Cold Sprayed
Self Lubricating Coatings

Cold Spray Action Team Meeting

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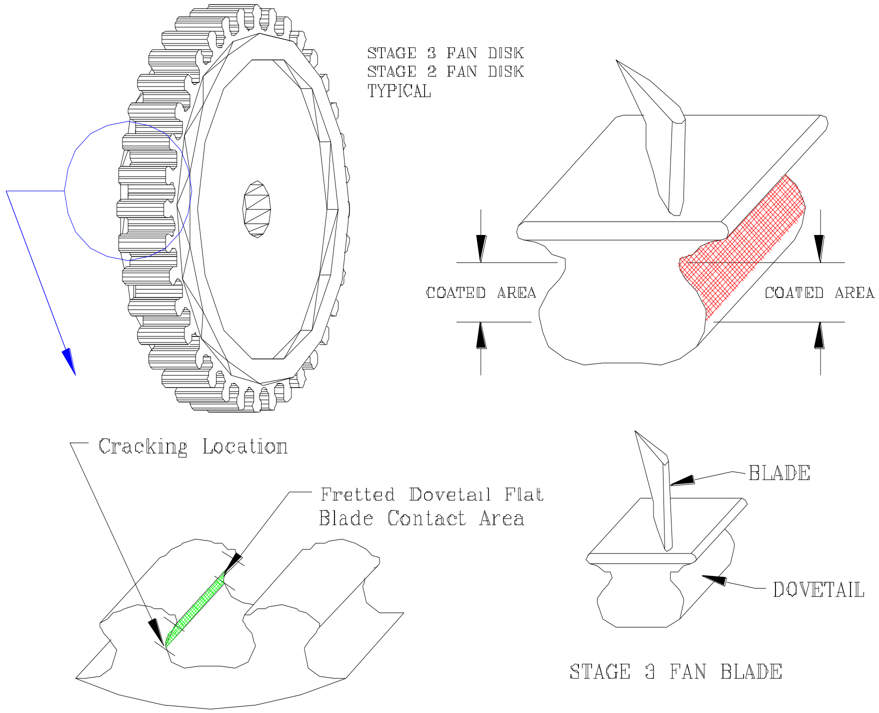
Presentation Outline

- Background
- Preparation of Coating Materials
- Nickel Encapsulation
- Cold Spray Deposition
- Coating Evaluation
- Summary

Objective

To create and apply self-lubricating coatings that will improve wear and mechanical properties of mating surfaces.

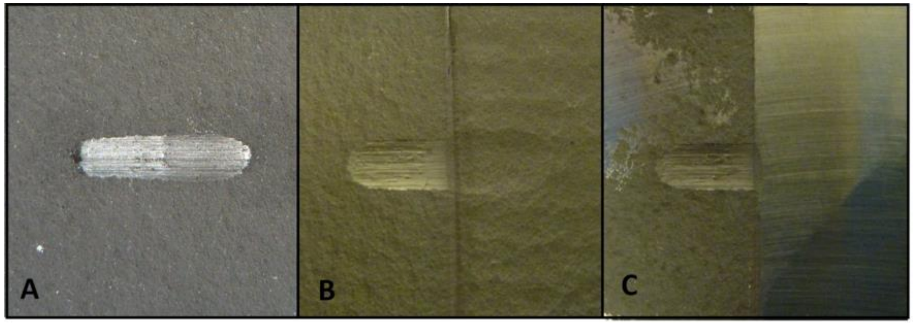


Background

- Solid lubricant are used in several applications
- Once the solid lubricant is depleted, the wear rate greatly increases
- Solid lubricant particles can be encapsulated in metal
- Composite powder can be deposited on the wear surface
- Thermal spray would melt the metal and solid lubricant
- Cold Spray can deposit the encapsulated powders without melting or destroying the powders

Self-lubricating Coatings – Background

- Composite materials (Encapsulated solid particles)
- Can be used to improve surface properties
  - Reduce the coefficient of friction
  - Improve wear resistance
- Functionally gradable
- Repairable



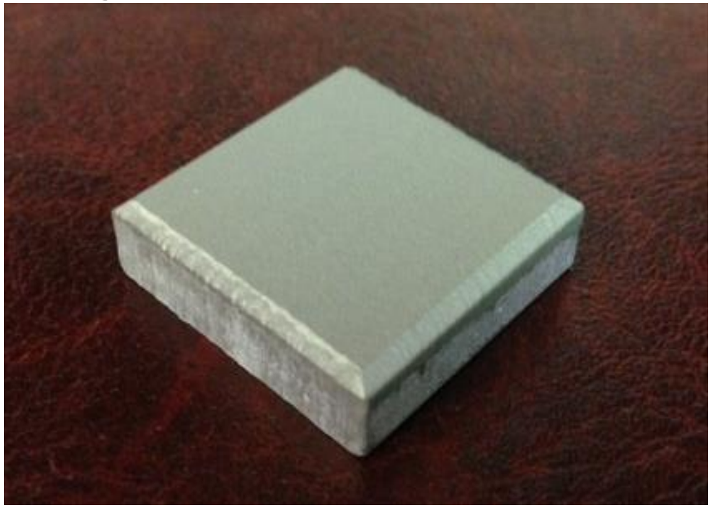
Partially repaired wear damage of hBN-Ni coating on Aluminum

Process Optimization

- Size of solid lubricant
  - Minimize diameter of the coated particle
- Encapsulation process
- Ni coating
  - Minimum thickness to prevent fracture of the lubricant
  - Minimum thickness to ensure plastic deformation and bonding
- Velocity
  - Deposition efficiency
  - Good adhesion
- Temperature
  - Velocity
  - No damage to the solid lubricant particle

Preparation of Coating Materials

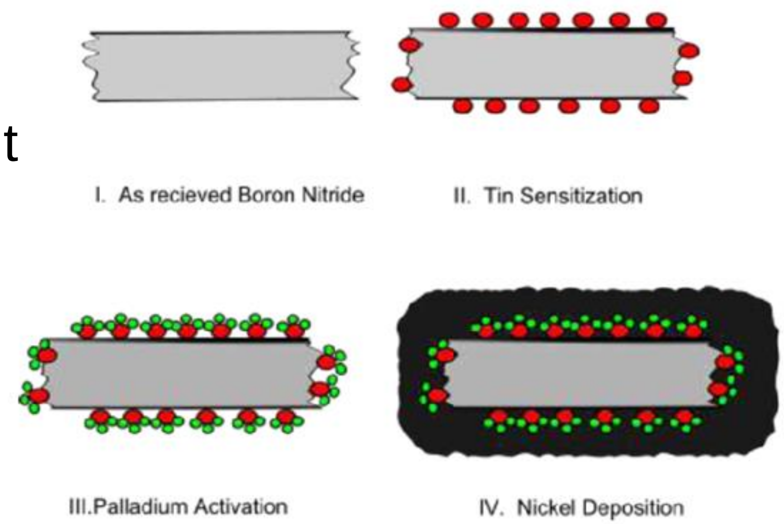
- Self-lubricating coating material composed of :
  - **Hexagonal Boron Nitride (hBN)** (lubricant)
  - **Nickel** (matrix)
- Nickel was selected due to:
  - Relatively high temperature capability
  - Potential for work hardening



Cold Spray coating on
Al-6061 substrate

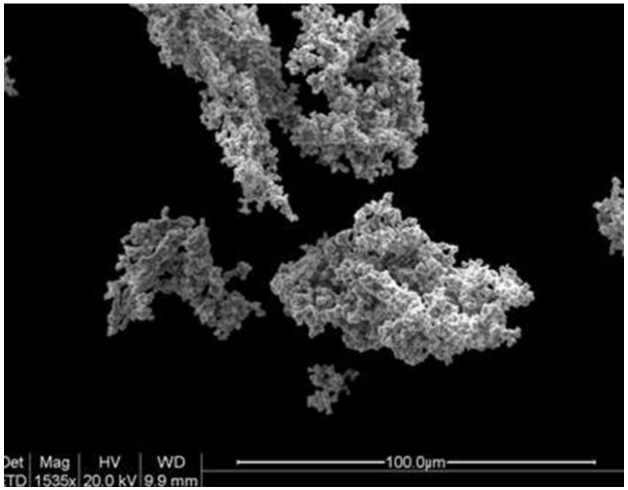
Preparation of Coating Materials

- hBN-Ni powder preparation:
  - Activate hBN surface with (Sn and Pd Chloride)
  - Ni deposited onto hBN particles via electroless Ni plating
- Thick Ni encapsulation via two-solution electroless Ni plating
  - Required for Cold Spray deposition
  - Better wear resistance and excellent corrosion behavior
- Mix hBN-Ni with Ni

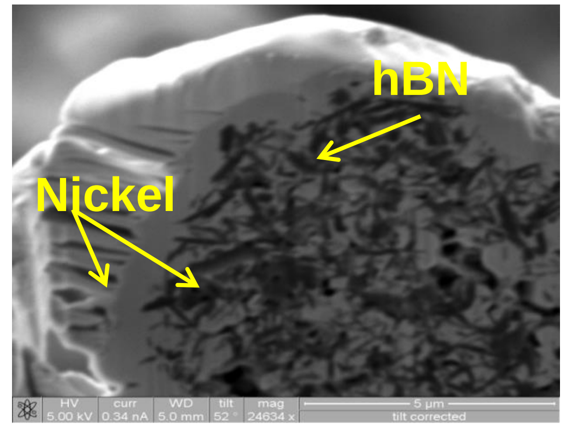


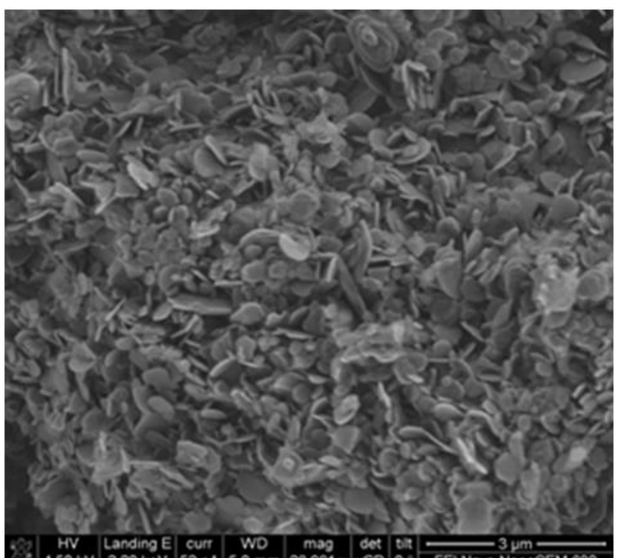
Preparation of Coating Materials

- Particles of hBN encapsulated with Nickel

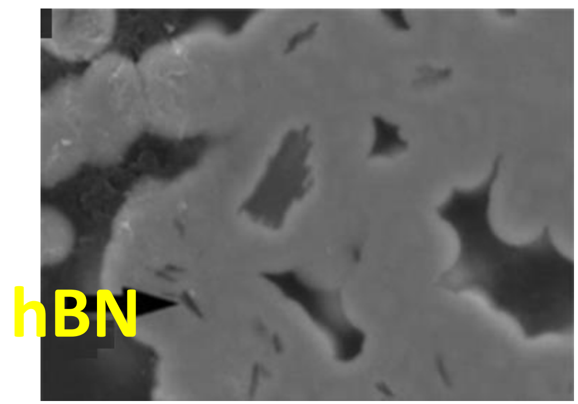


Coated
hBN Particles





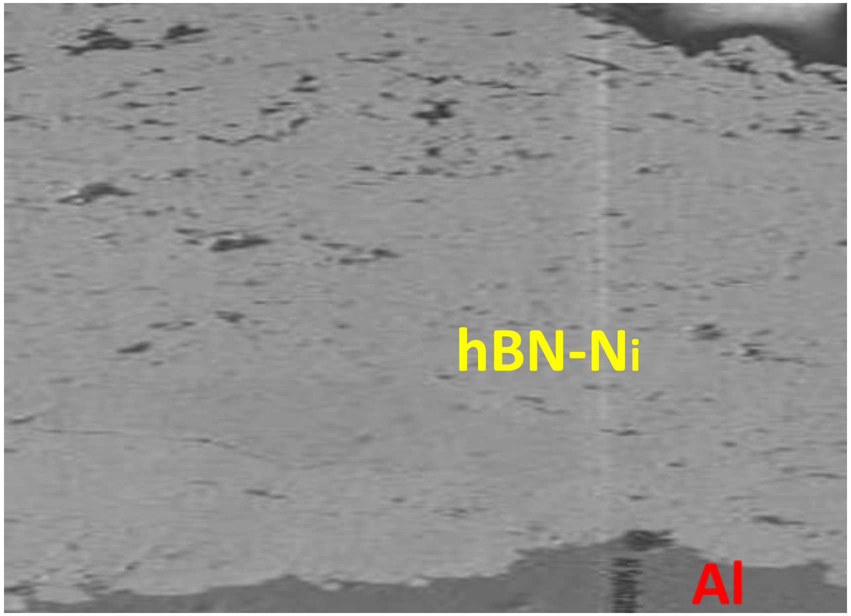
hBN Particles



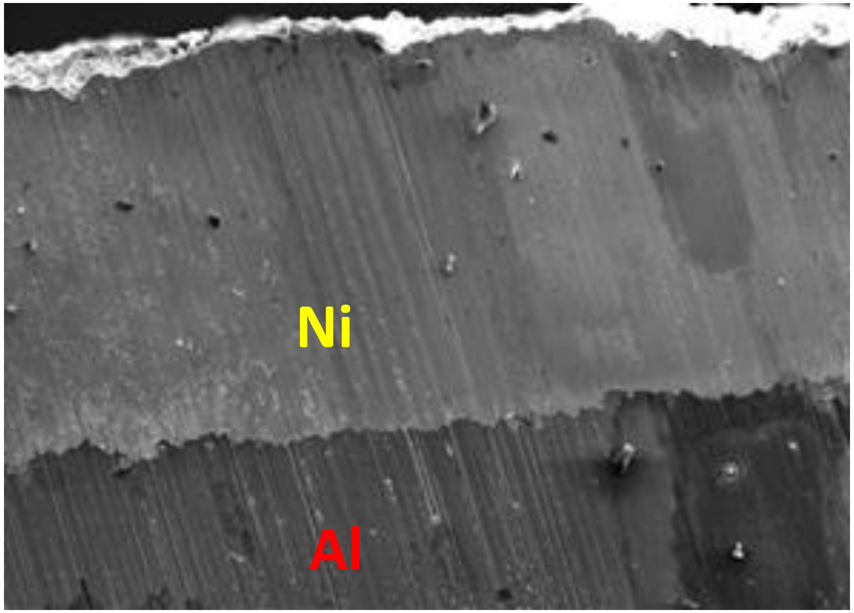
hBN encapsulated with Nickel particles (1 wt% hBN)

Application of Coating

- Al 6061 coated with hBN-Ni and Ni



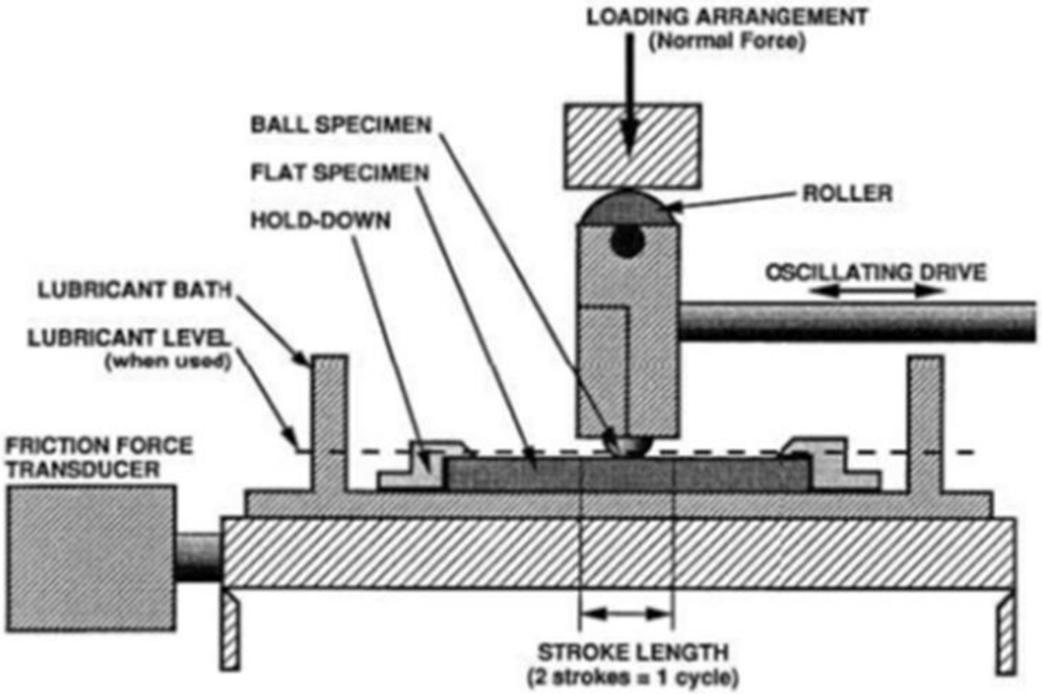
hBN encapsulated with Ni



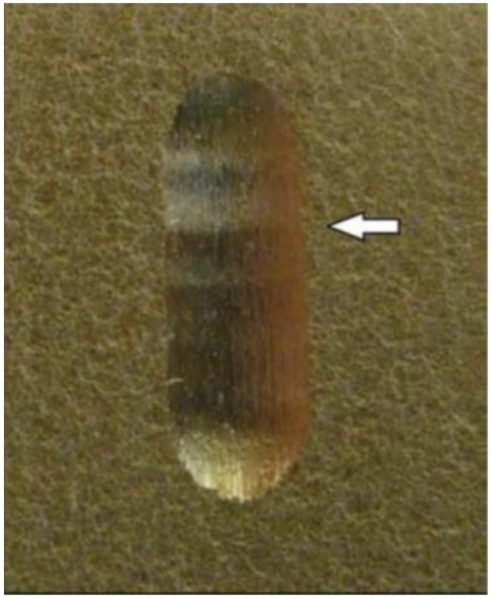
Pure Ni

Evaluation of Coated Surfaces

- Friction Test



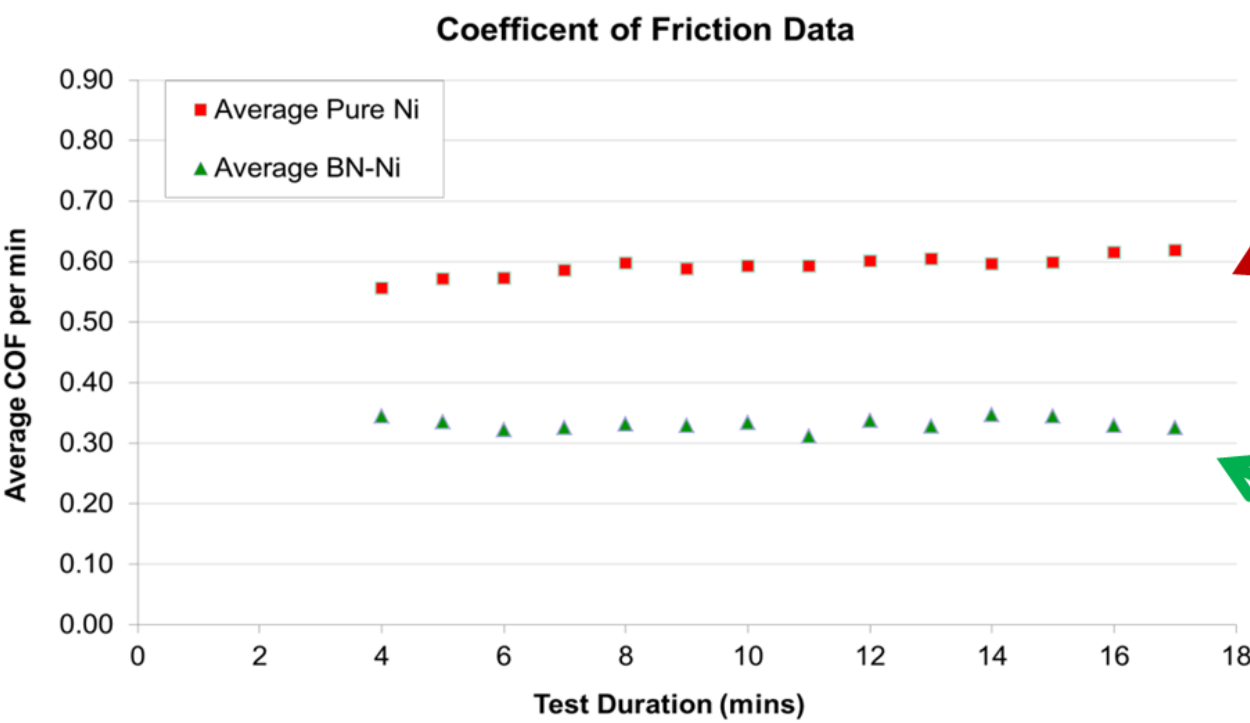
Reciprocating wear test
(ASTM International 2008)

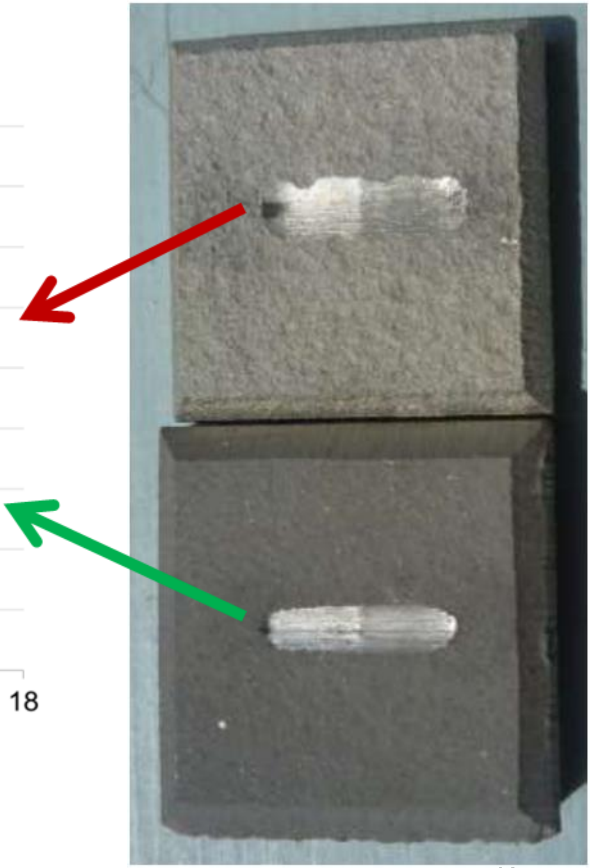


wear scar after the test

Evaluation of Coated Surfaces

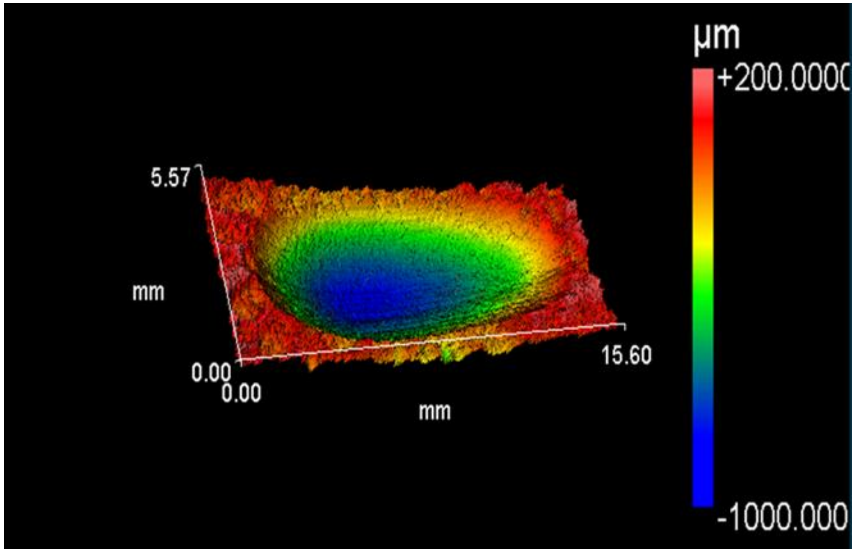
- Comparison of the coefficients of friction of the Ni and hBN-Ni



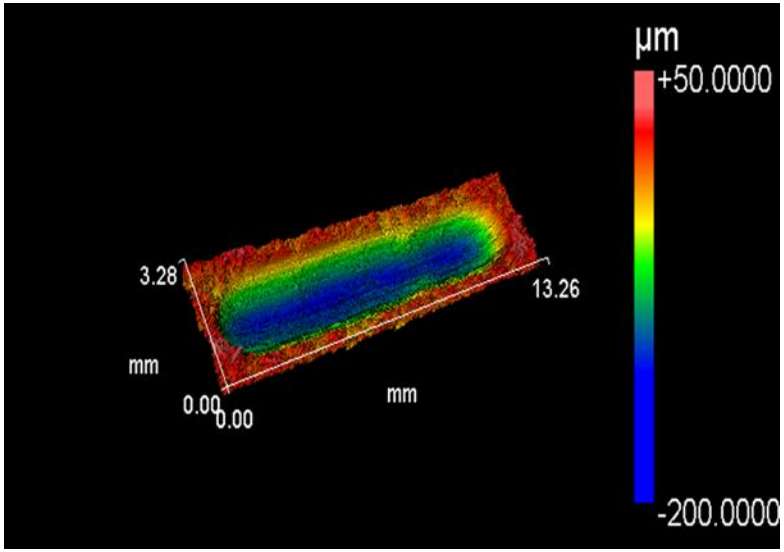


Evaluation of Coated Surfaces

- Profilometry depth profiles



Coated with Ni



Coated with hBN-Ni

Evaluation of Coated Surfaces

- Wear scar volume reduced by an order of magnitude

Material	Wear volume
Al 6061 coated with Ni	23.80 mm^3
Al 6061 coated with hBN-Ni	**2.13 mm^3**

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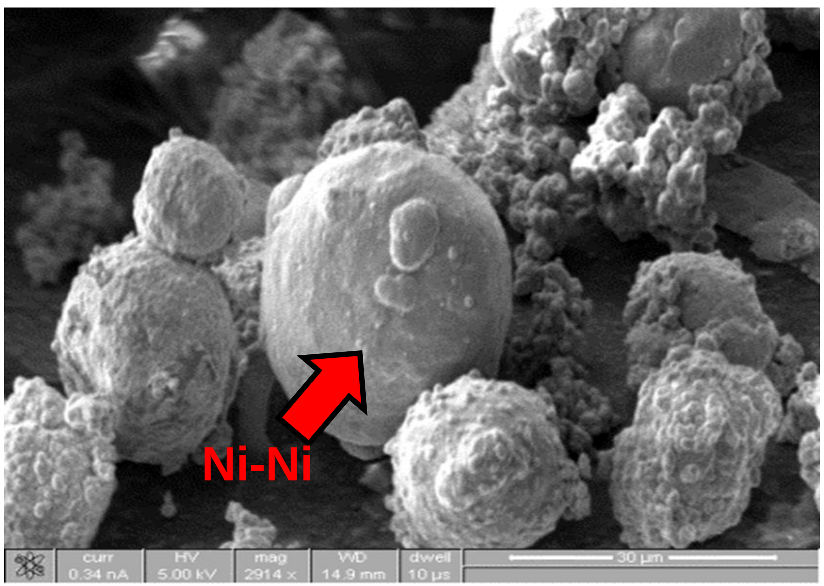
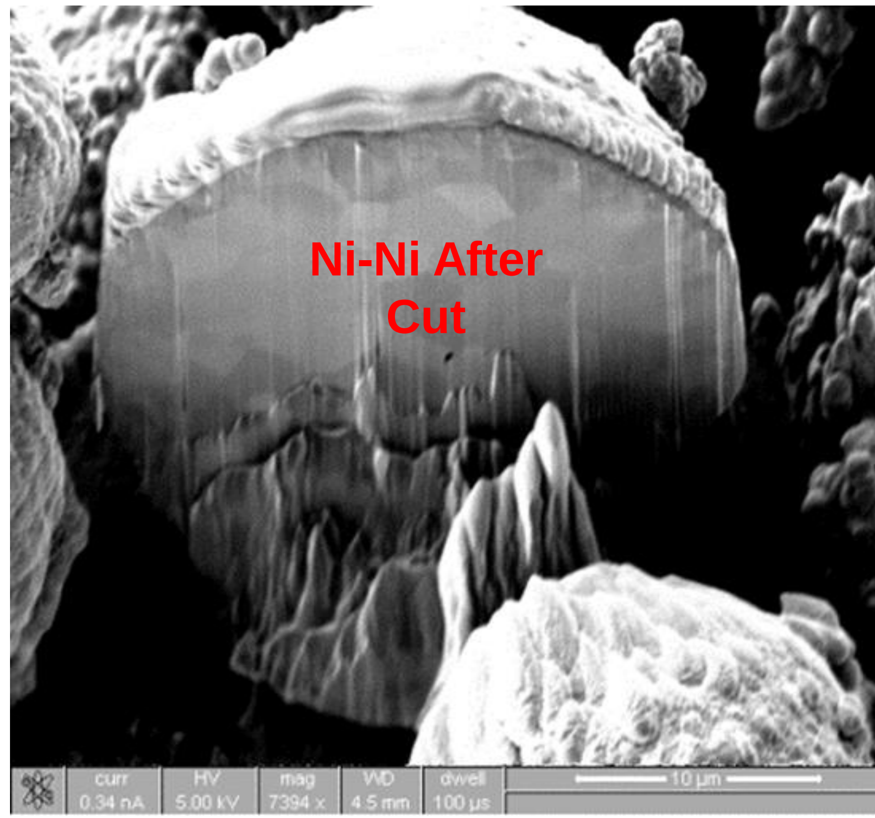
Evaluation of Ni-Ni Coated Particles

- Ni powder encapsulated with Ni
- Samples prepared using focused ion beam (FIB) milling





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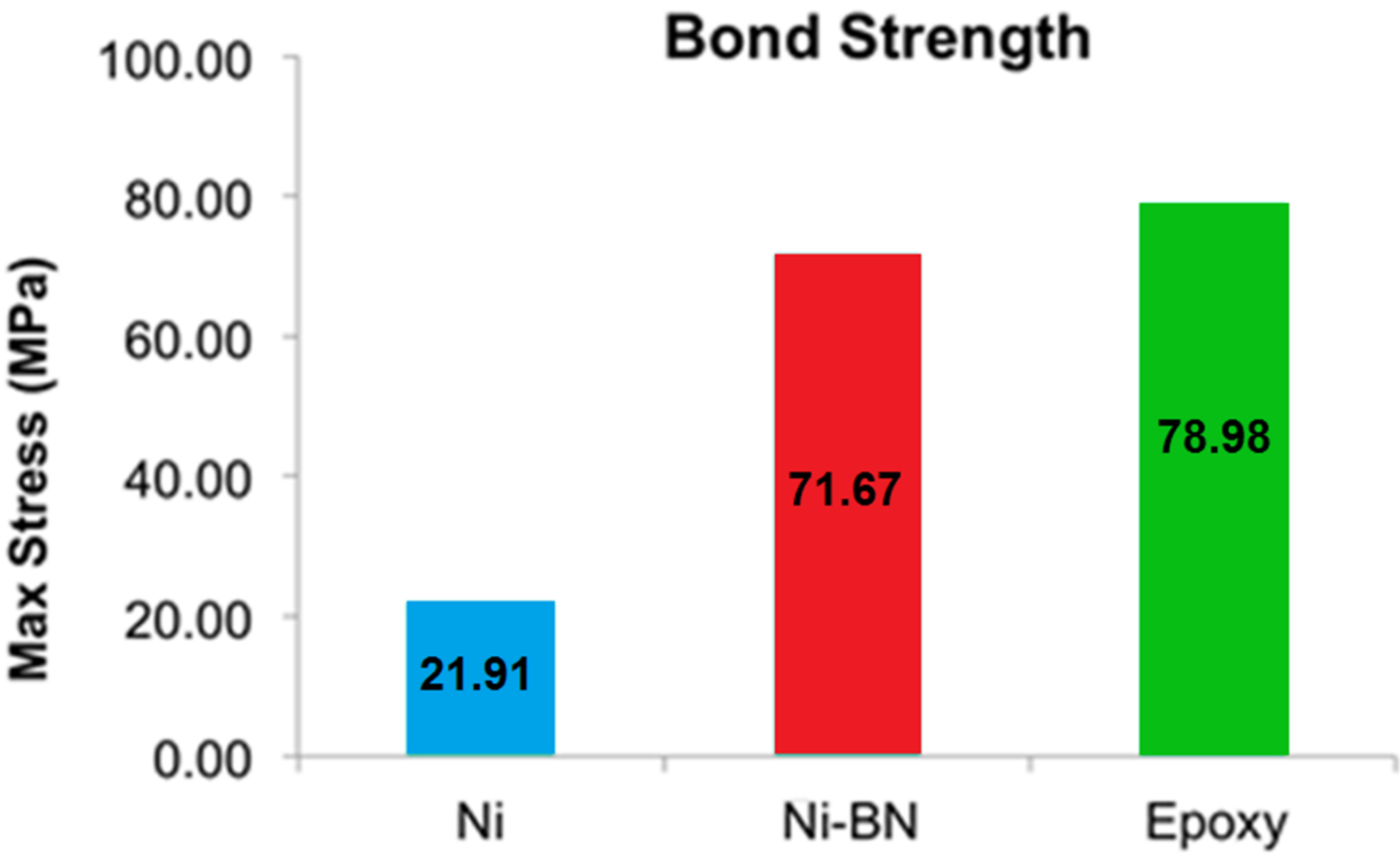
Evaluation of Coated Surfaces

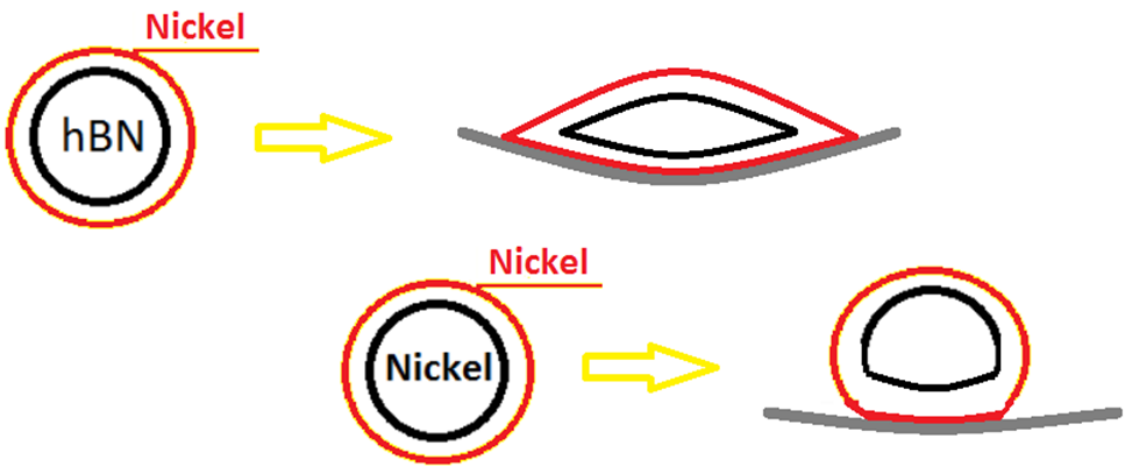
- Improved bond strength of hBN-Ni coating



Particle Deformation

- hBN-Ni has good adhesion strength
- Ni-Ni coating has poor adhesion strength

Initial ductility and work hardenability of nickel

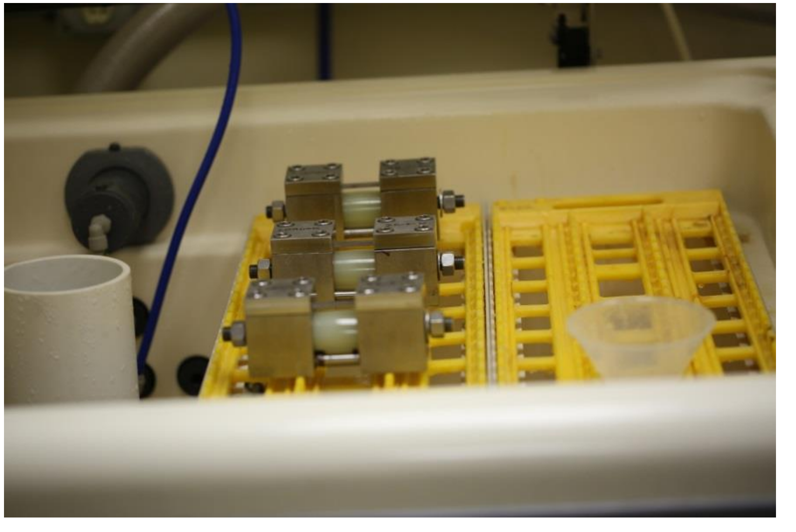


Conclusions

- Cold spray process and nickel encapsulation of hBN (hBN-Ni) allowed the creation of composite coatings with a metal matrix and uniformly dispersed solid lubricant particles
- hBN-Ni coatings:
  - Significantly higher bond strength
  - Markedly reduced coefficient of friction
  - Improved wear resistance (10x)
- Coatings were both repairable and functionally gradable
- Low temperatures of cold spray process also allows unique material and coatings (metal on glass, metal on plastics etc.)

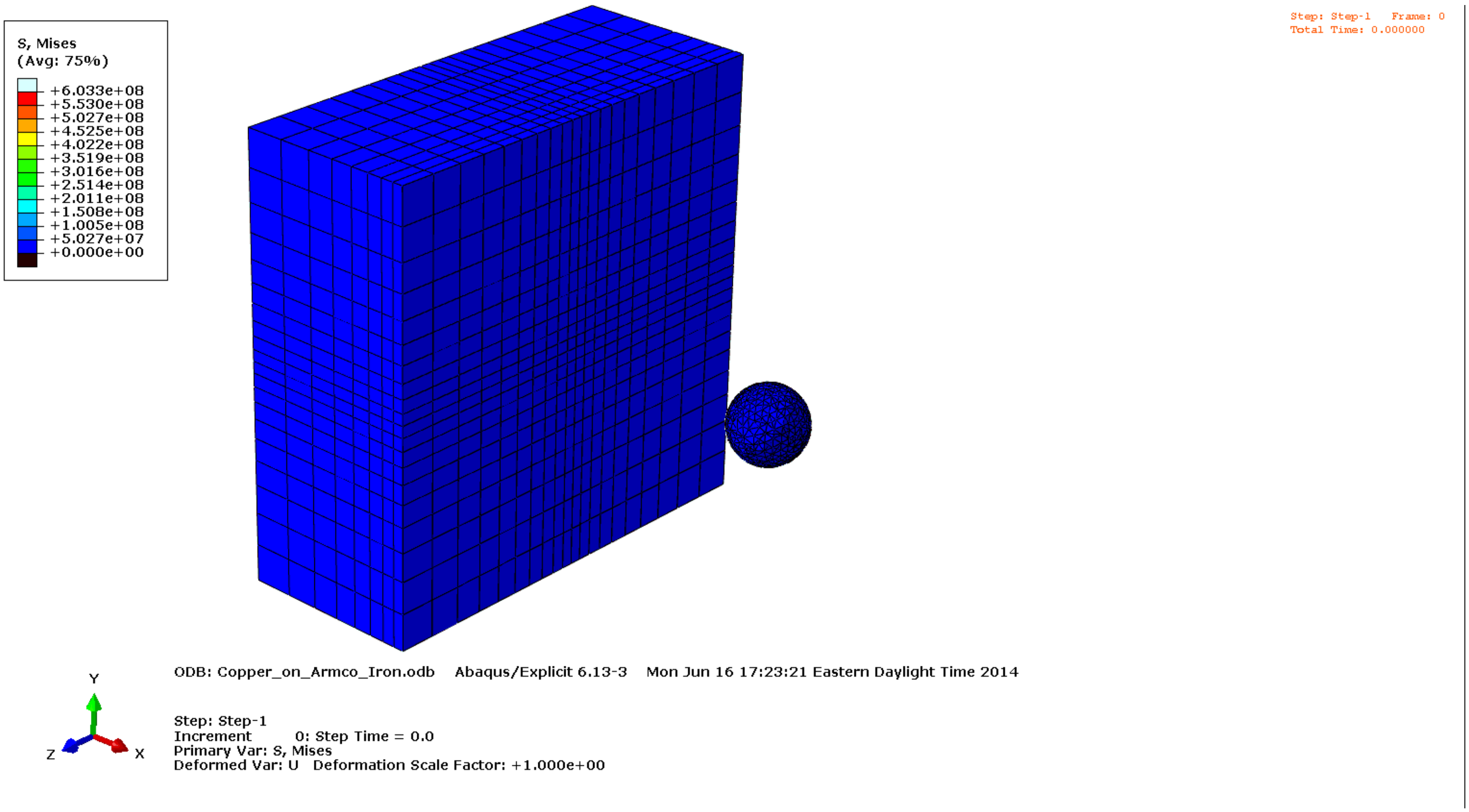
Stress Corrosion Cracking of Al-6061

- Wrought Al 6061-T6
- As Cold Sprayed
- Tensile tests for baseline following ASTM E8
- SCC following ASTM G49-85
- In process

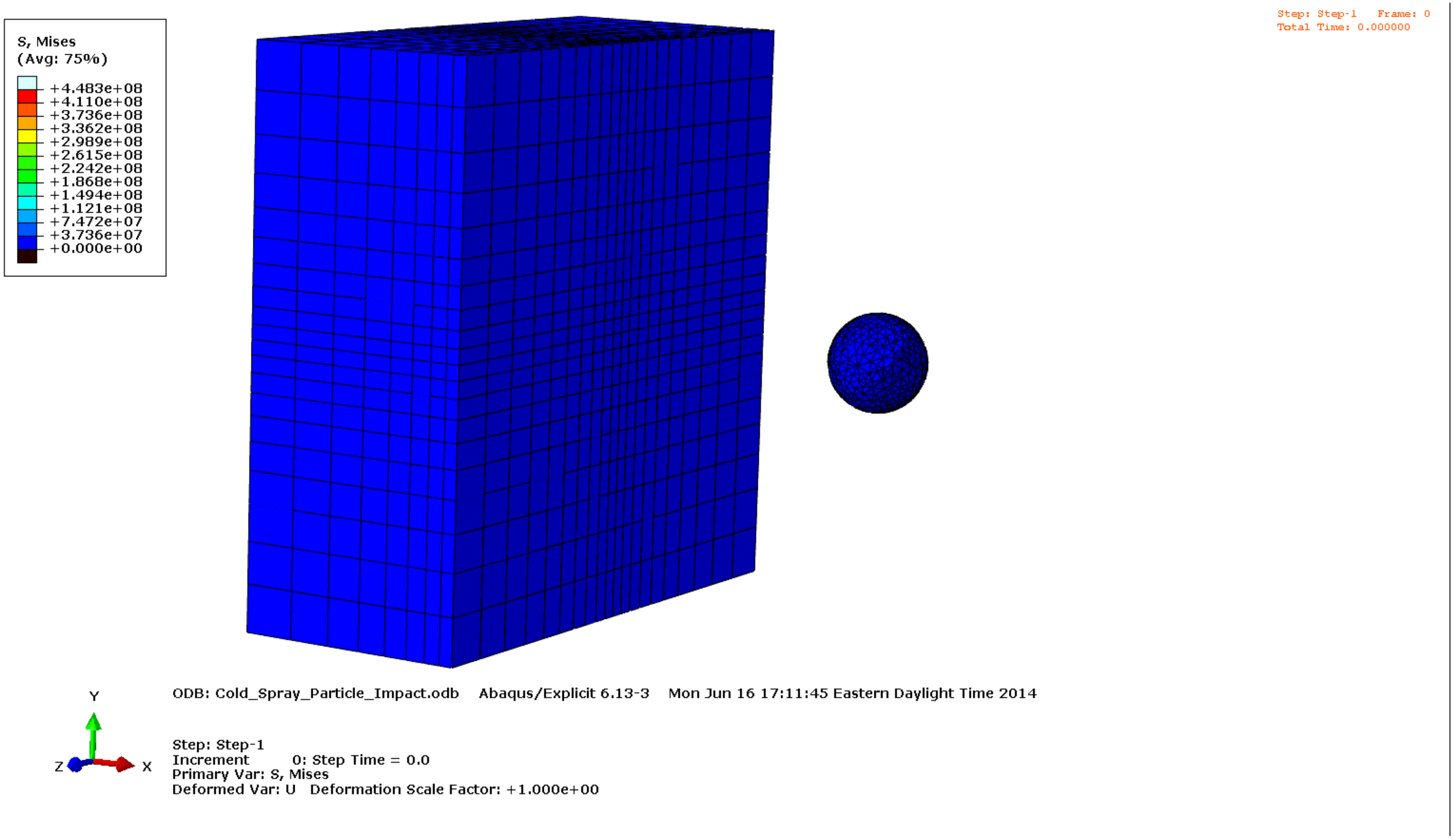


SCC Test Fixture

FEM of a Cu particle impacting Armco Iron – 500 m/s



FEM of a CP Al particle impacting Al 6061-T6 – 500 m/s



THANK YOU