CSAT Summer Meeting 2013

Advancements in Cold Spray

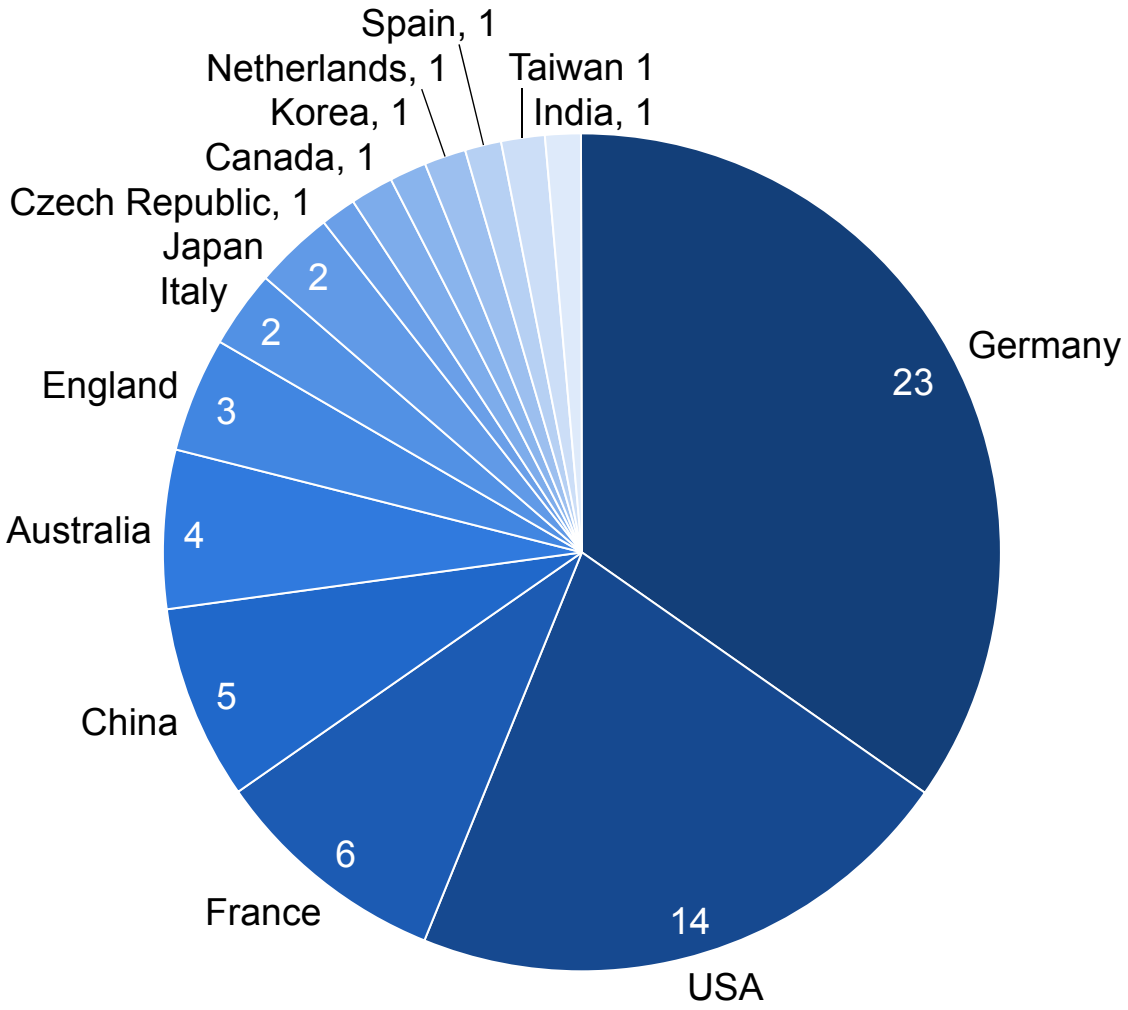
SULZER

Sulzer Metco

Jochen Tewes | June 19th 2013

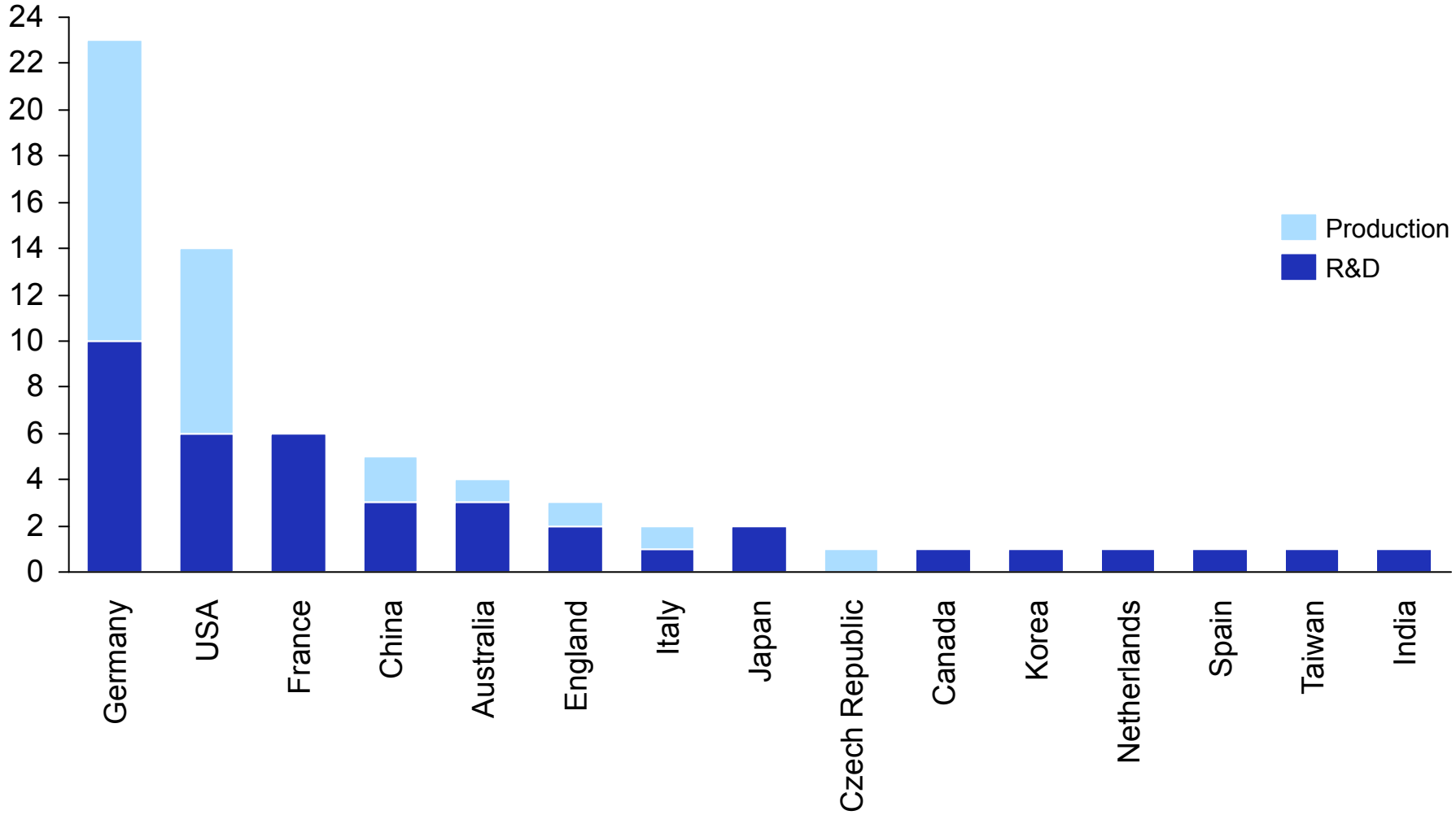
Installed base

Total number of installed systems: 68 without upgrades

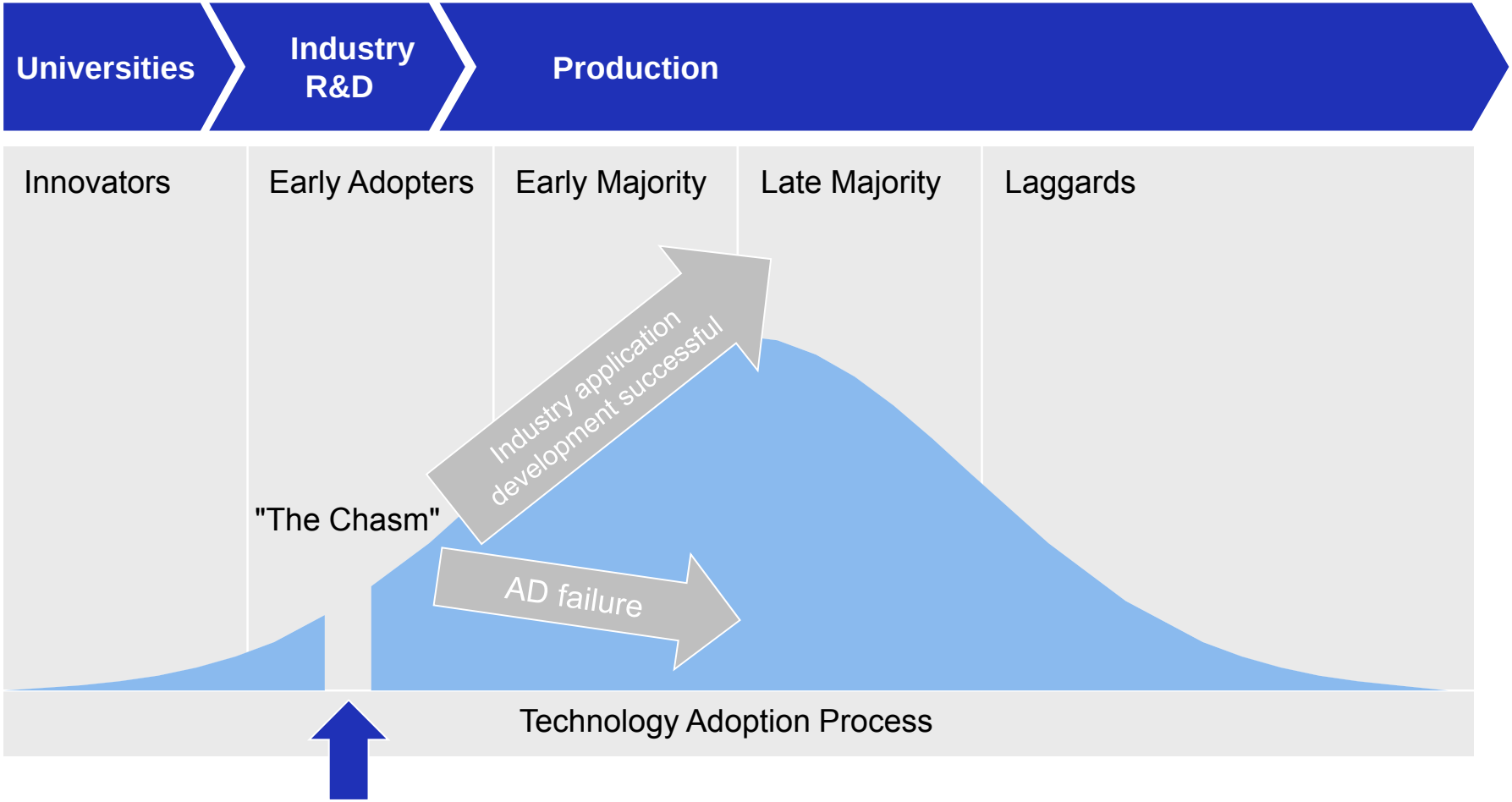


Installed base

Number of installed systems in R&D and Production per country



Market Development Stage: Early adopters



Market today

- Still a small market
- Evolving from R&D into industrial
- A lot of attention and expectations

Cold Spray Market with Potential

	CHF m
Market p.a.:	300-500
Equipment	15%-25%
Materials	25%-35%
Service	40%-60%

Aerospace

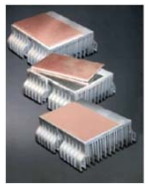
++++

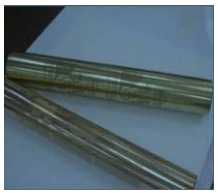
- Magnesium alloy cast components
- Propeller blades

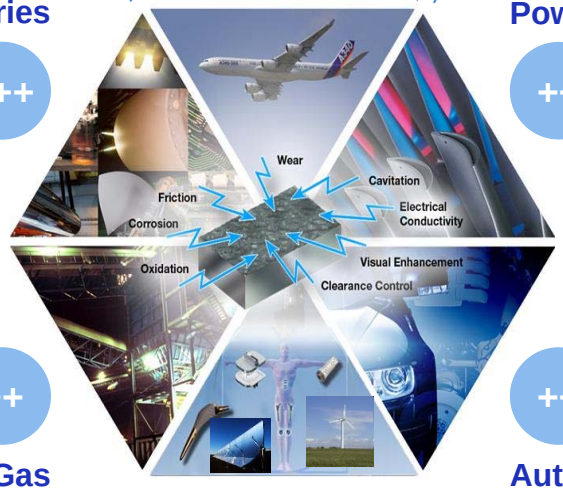
Steel, Paper and Other industries

+++

- Aluminum heat sinks
- Gravure rolls rebuild (Cu and/or Zn alloys)
- Copper mould rebuild







Power generation/Power savings

++

- Coating of ball valves
- Electrical contact on protective tubes for high voltage DC power lines

Oil & Gas and Mining

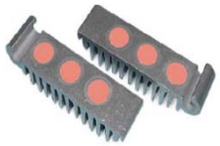
++

Automotive

++

New Technologies

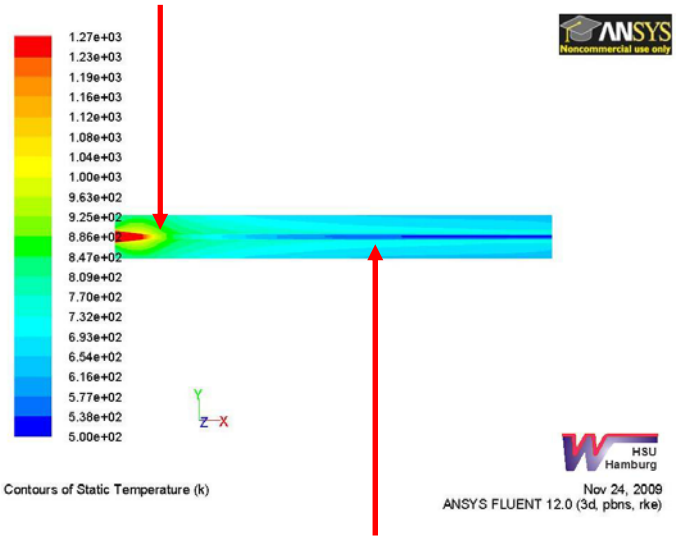
++



Coating and Process Developments

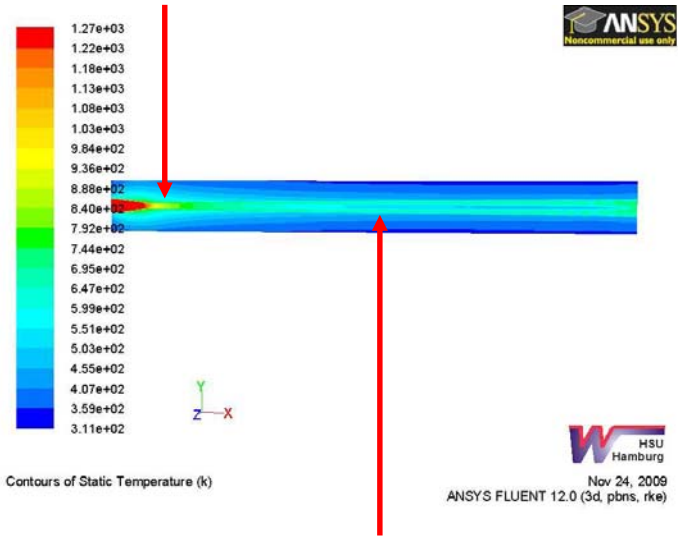
Nozzle Cooling: Nozzle and Gas Temperatures

T(wall) at throat: **710 ºC**



T(gas) 90 mm downstream throat: **320 ºC**

T(wall) at throat: **460 ºC**



T(gas) 90 mm downstream throat: **280 ºC**

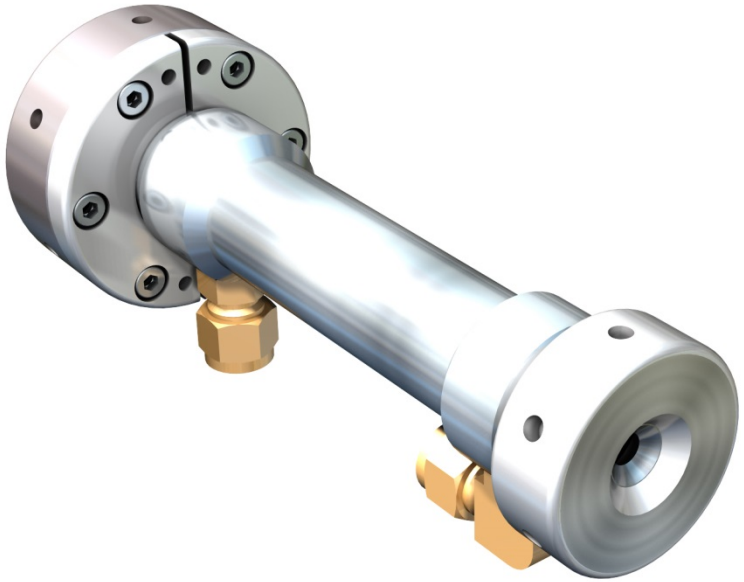
HELMUT SCHMIDT UNIVERSITÄT
Universität der Bundeswehr Hamburg

Water cooling:

- Significantly lower wall temperatures, no nozzle plugging,
- Slightly lower process gas temperature (≈ 40 ºC), particle temperature (≈ 30ºC)

Equipment

Nozzle Cooling: Technical Design by Sulzer Metco



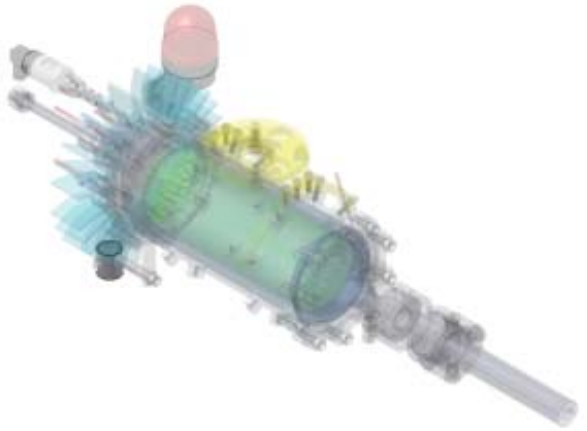
Cold Spray Nozzle Water-cooling

- Enables longer spraying times and/or higher gas temperatures without nozzle clogging
- Can be run with a chiller or tap water
- Adaptable to existing systems Kinetiks™ 4000 and Kinetiks™ 8000

Equipment – New Cold Spray Gun

Kinetiks™*Pro*-1000

- No pre-heater required
- 60 kW @ 400V 3xPh
- Gas in 20 ºC, out 1000 ºC (1200 ºC)
- Light cables, full motion capability



Kinetiks™ 8000

- Pre-heater required
- 22 kW @ 480V 3xPh
- Gas in 20 ºC, out 1000 ºC
- Limited kinematics due to hot gas tube

Overview – Materials

Metals	Alloys	Composites
Tin (Sn)	MCrAlYs	Ceramics + Metal matrix
Zinc (Zn)	Ti6Al4V	Anatase – TiO_2 (nanosize)
Aluminum (Al)	Bronze	
Iron (Fe)	Brass	
Copper (Cu)	Inconel (different types)	
Nickel (Ni)	316L	
Titanium (Ti)	430L	
Tantalum (Ta)	CuSn	
Niobium (Nb)	CuMnNi	
Zirconium (Zr)	NiCr	
Silver (Ag)	NiTi	
Gold (Au)	CuW	

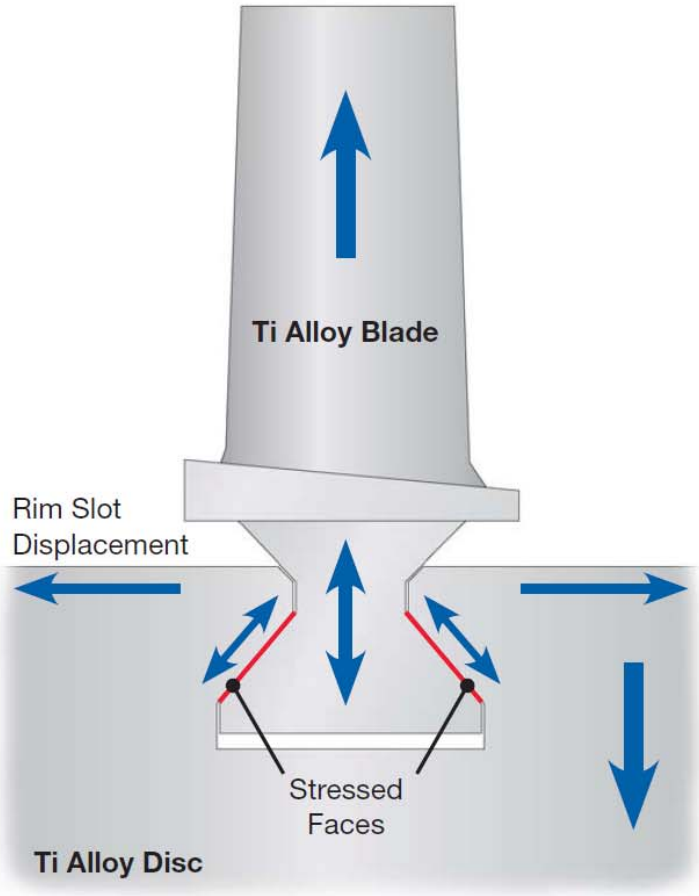
Some materials may require high levels of He to spray

Application Driven Investigation on Cu-Ni-In

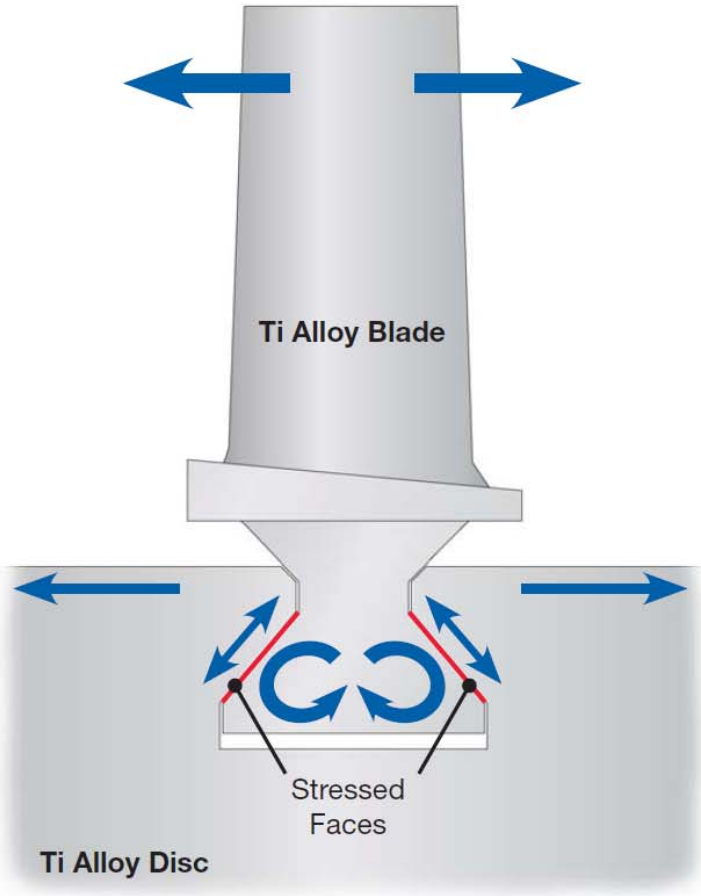
- Cu-Ni-In is a copper based alloy used to protect metal-to-metal wear of titanium alloy parts like fretting, galling and cavitation
- Conventionally, these coatings are deposited using atmospheric plasma spray (APS) or by combustion powder Thermospray™ and are mostly used in the as-sprayed condition
- The addition of indium helps to improve the anti-galling and lubricating characteristics of the coating
- Applied to turbine engine blade roots or disk slots, expansion joints, and/or compressor air seals and approved by major turbine engine OEMs

Background Information on Cu-Ni-In – Applications

Sources of Fretting Fatigue in a Blade and Disc System

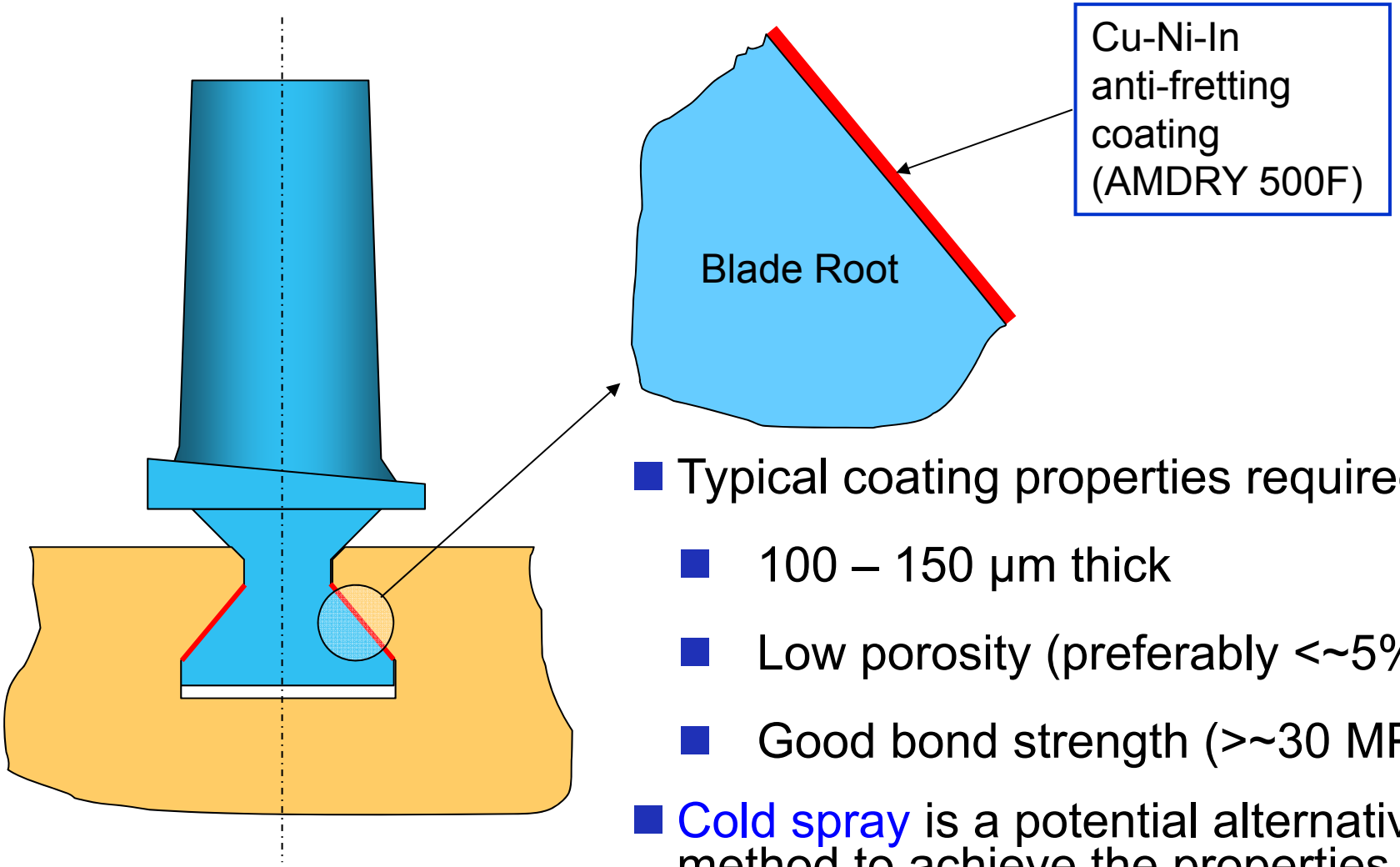


Radial Strain:
With changes in disc speed, the slot can open and the blade moves outward under centrifugal load. Thus, slip along the surface of the dovetail occurs.



Blade Vibration:
The primary source of blade vibration is from aerodynamics, which causes the blade to oscillate. Thus, slip along the surface of the dovetail occurs.

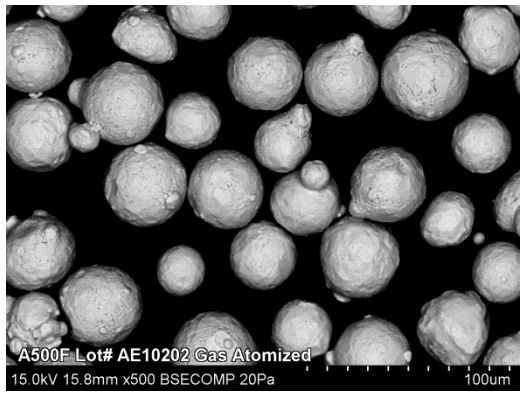
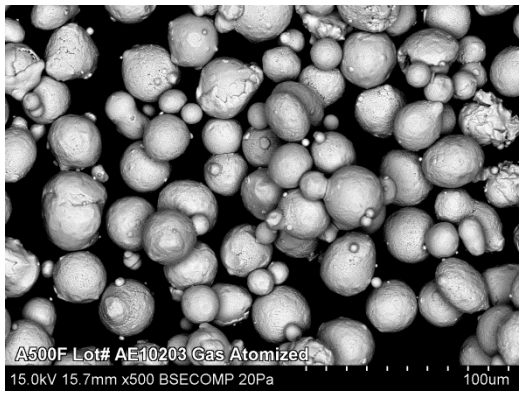
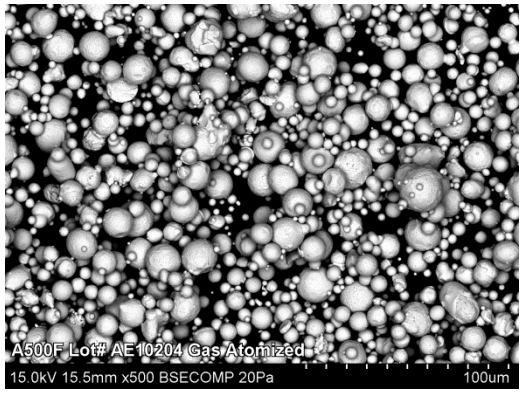
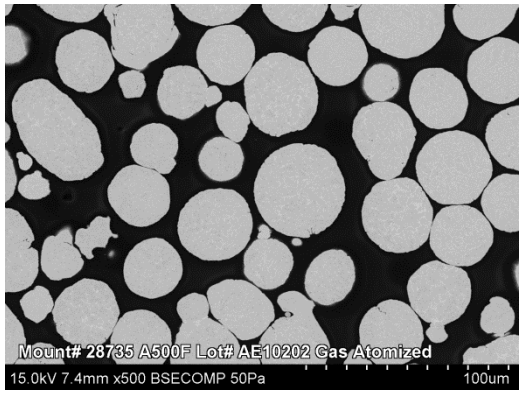
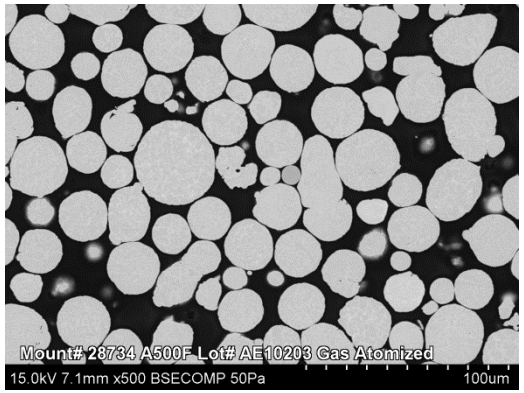
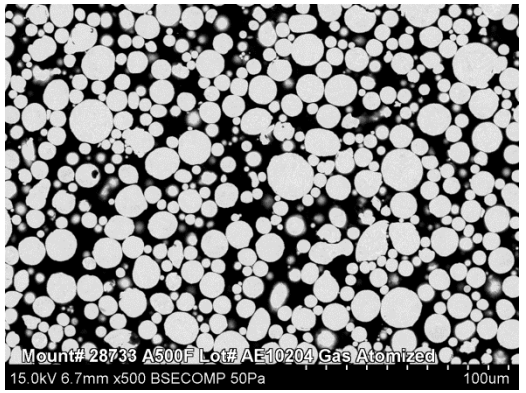
Background Information on Cu-Ni-In – Applications



- Typical coating properties required:
  - 100 – 150 µm thick
  - Low porosity (preferably <~5%)
  - Good bond strength (>~30 MPa)
- Cold spray is a potential alternative method to achieve the properties listed above and should be explored

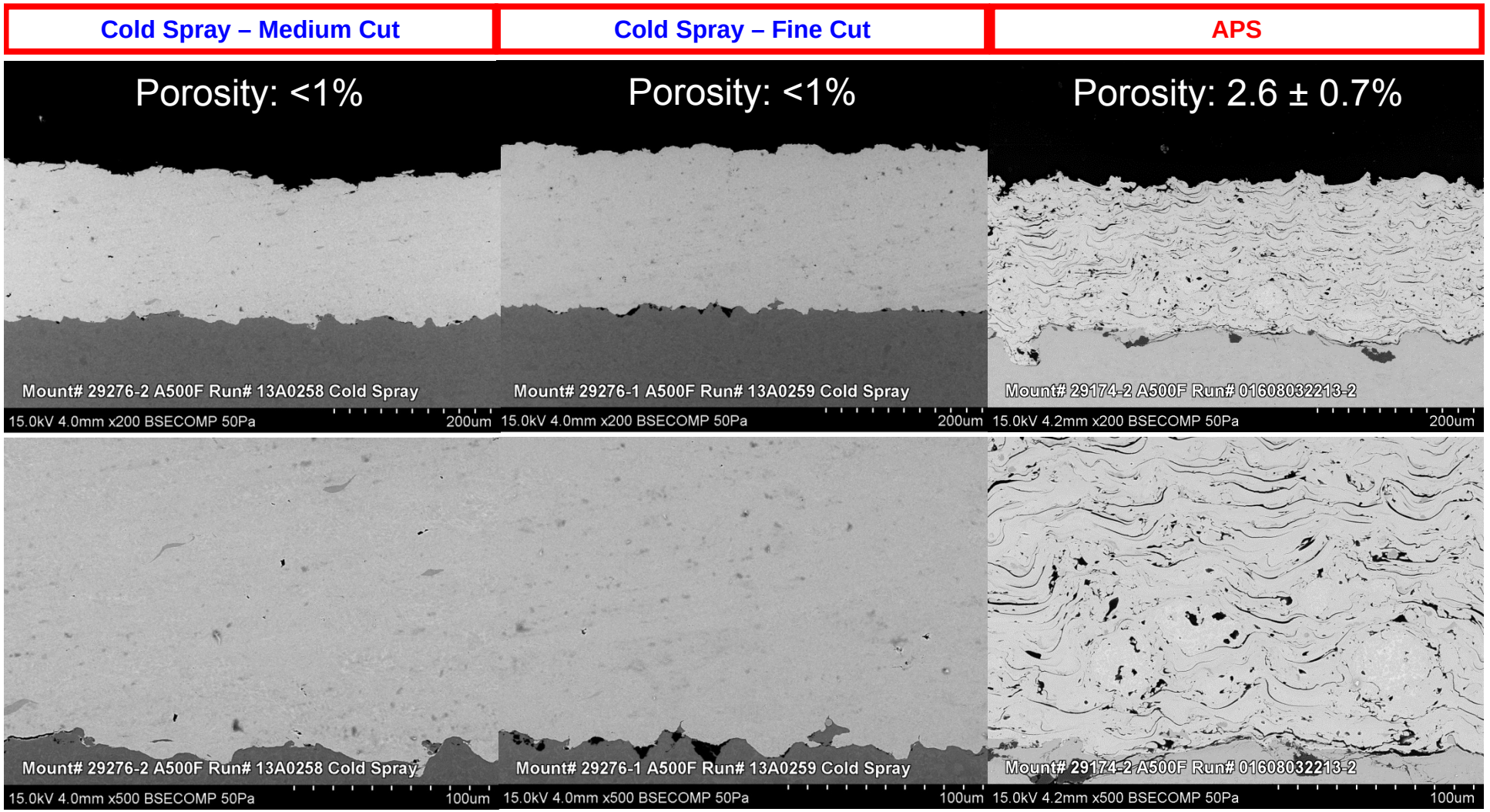
Application Driven Investigation on Cu-Ni-In

- Cu-Ni-In – Sulzer Metco feedstock powders investigated:
  - Coarse: -45+15 µm (AMDRY 500F) – Existing powder product
  - Medium: -38+11 µm (AE10203) – Cold spray experimental powder
  - Fine: -22+5 µm (AE10204) – Cold spray experimental powder

Coarse	Medium	Fine
		
		

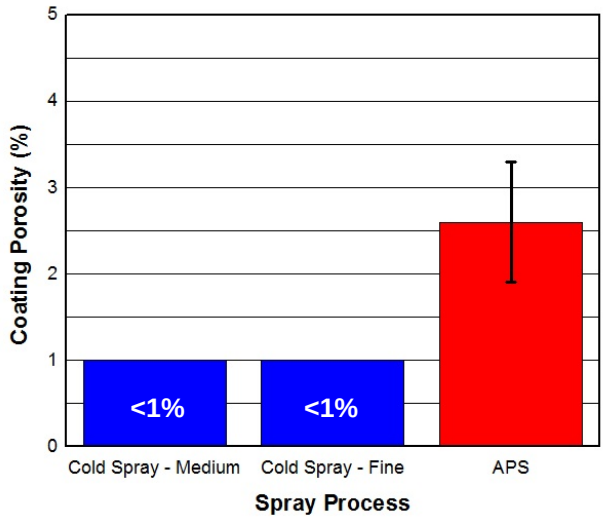
Application Driven Investigation on Cu-Ni-In

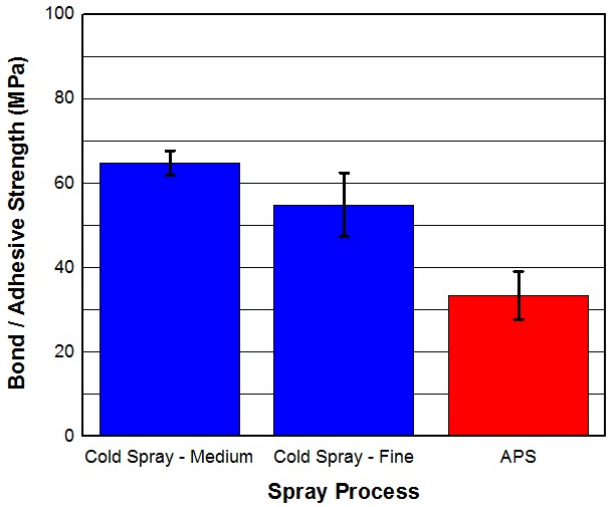
- Coatings comparison: Cold Spray (medium & fine cuts) – APS

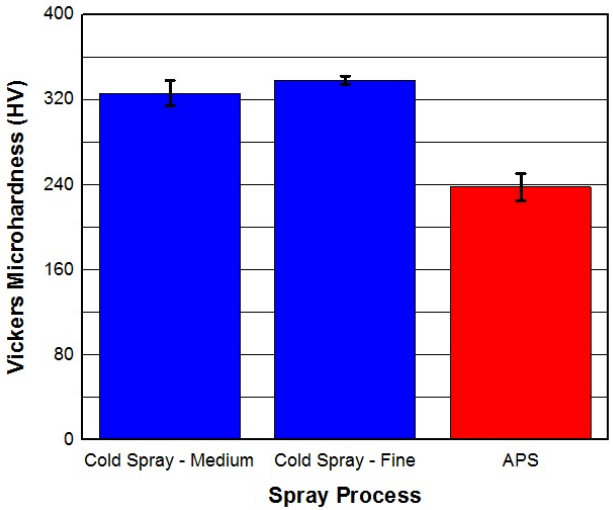


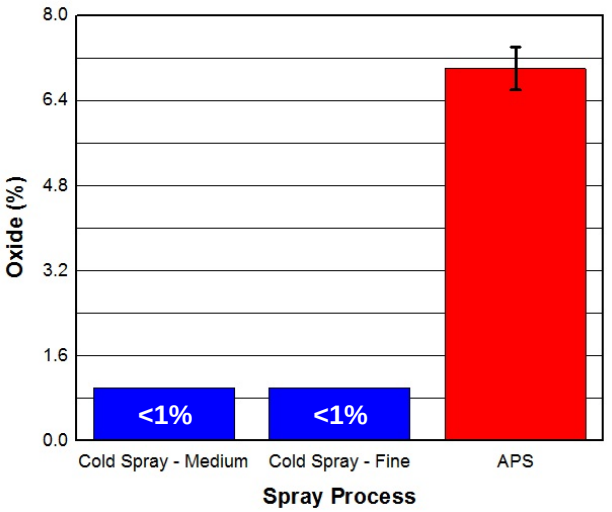
Application Driven Investigation on Cu-Ni-In

- Coatings comparison: Cold Spray (medium & fine cuts) – APS









Application Driven Investigation on Cu-Ni-In

- Coatings comparison: Cold Spray (medium & fine cuts) – APS

	Powder	Cold Spray (Med. & Fine)	APS
Major Phase	74.9% Cubic $Cu_{0.5}Ni_{0.5}$	100% Cubic $Cu_{0.5}Ni_{0.5}$	98.4% Cubic $Cu_{0.5}Ni_{0.5}$
Minor / Trace Phase	25.1% Cubic $Ni_{0.92}In_{0.08}$	---	1.6% Cubic Cu_2O

- As expected, a new phase was found for APS coating due to the high operating temperature of this process (Cu_2O)
- For both the Cold Spray and APS coatings, the trace phase from the feedstock powder vanished. Further investigation is required to draw firm conclusions

Application Driven Investigation on Cu-Ni-In

- These Cold Spray Cu-Ni-In coatings were deposited using:
  - Sulzer Metco Cu-Ni-In fine powders (-22+5 µm – AE10204) or
  - Sulzer Metco Cu-Ni-In medium powders (-38+11 µm – AE10203)
  - Sulzer Metco Kinetiks 8000 cold spray system
- Coating properties required to fulfill the above applications:
  - ✓100 – 150 µm thick
  - ✓Low porosity (preferably <~5%)
  - ✓Good bond strength (>~30 MPa)
- Based on the main desired Cu-Ni-In coating properties, Cold Spray coatings seem to outperform APS coating

Application Driven Investigation on Cu-Ni-In

Future Work

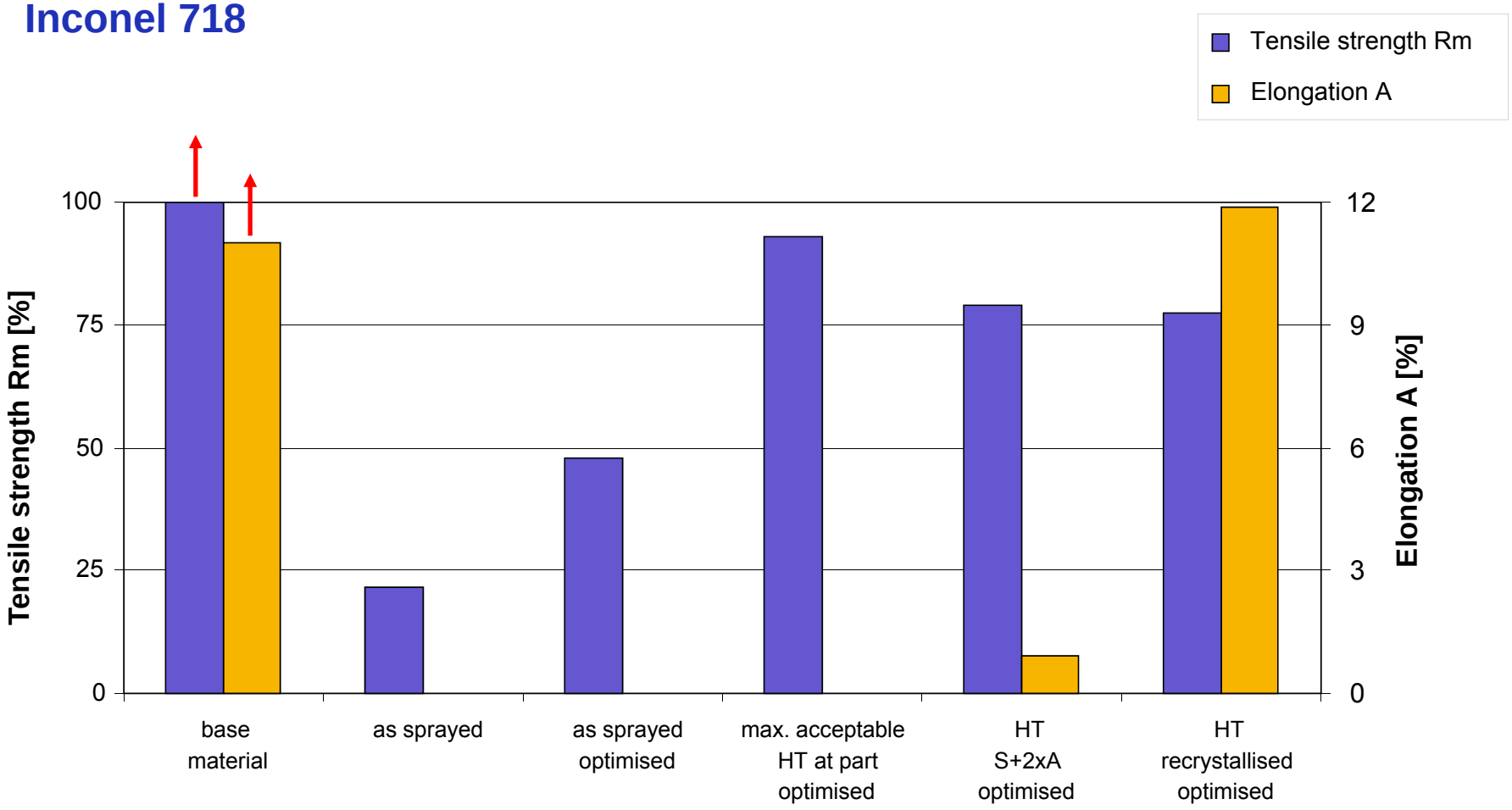
- There is potential in using Cold Spray to deposit Cu-Ni-In coatings and to achieve the required properties for targeted applications
- Additional studies and optimizations on the influence of feedstock powder size distributions on the resulting cold sprayed coatings will be investigated
- Performance tests: Sliding wear tests will be performed on cold and thermal sprayed coatings to simulate real life applications
- All work described above will be soon available in the open literature

Cold Spray Materials Development

Bond Coat Alloys NiAl , NiCrAl, MCrAlY	Bond Coats for TBCs
Ni Based Superalloys IN 718, 738	Rebuild and Additive Manufacturing
Aluminium Alloys 1100 , AlMg, AlSi	Rebuild and Additive Manufacturing
Titantium Alloys Pure Ti, Ti6Al4V	Rebuild and Additive Manufacturing

Coating development

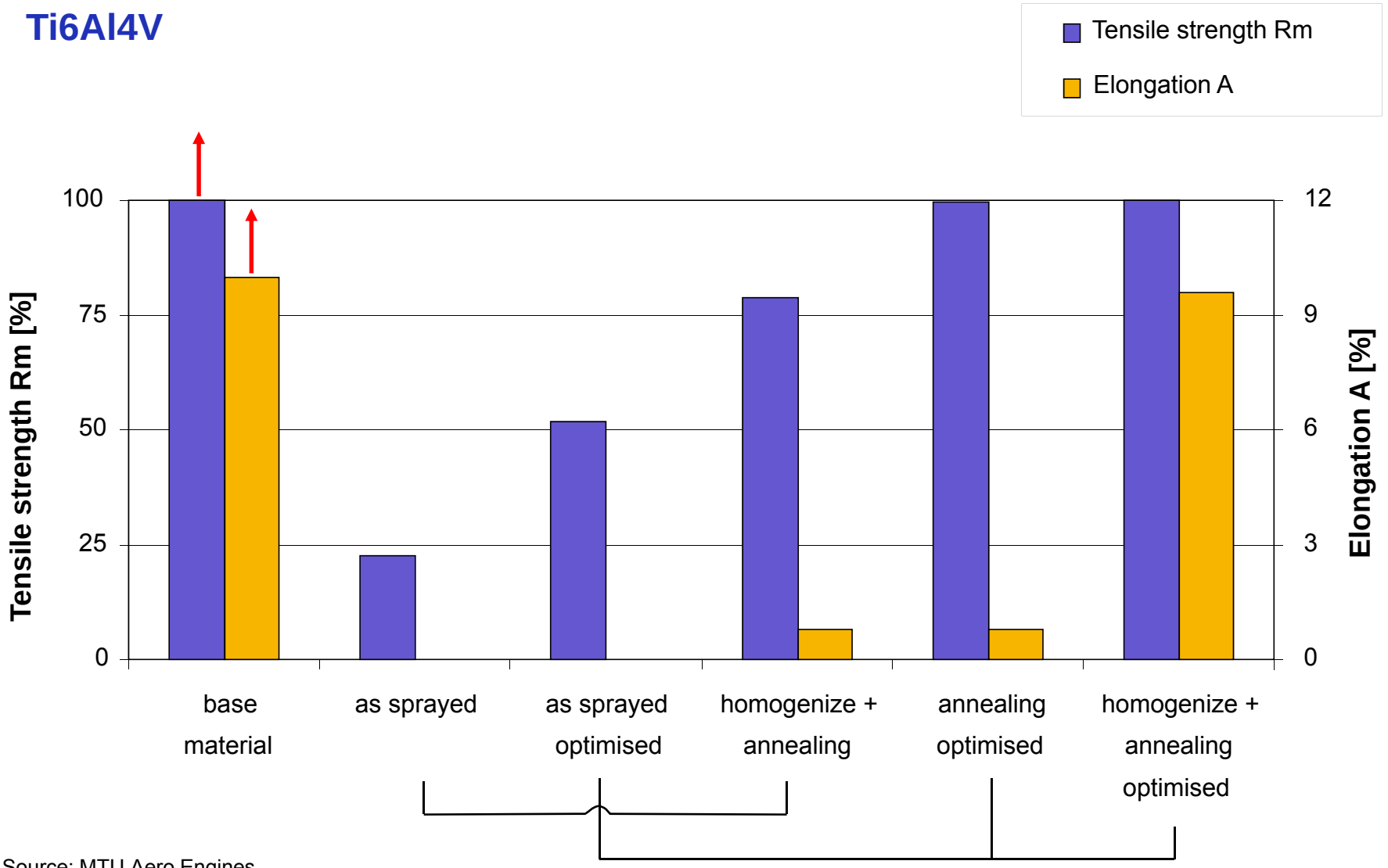
Inconel 718



Source: MTU Aero Engines

Coating development

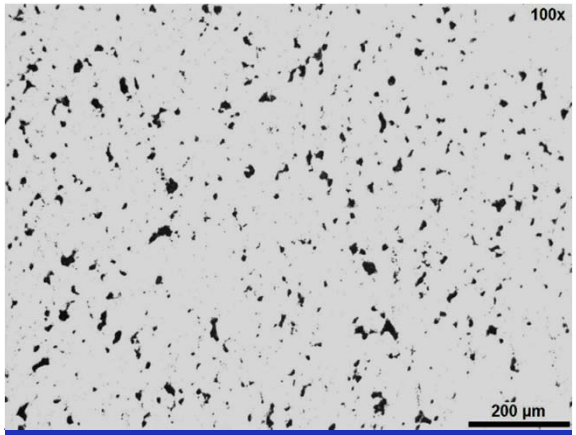
Ti6Al4V



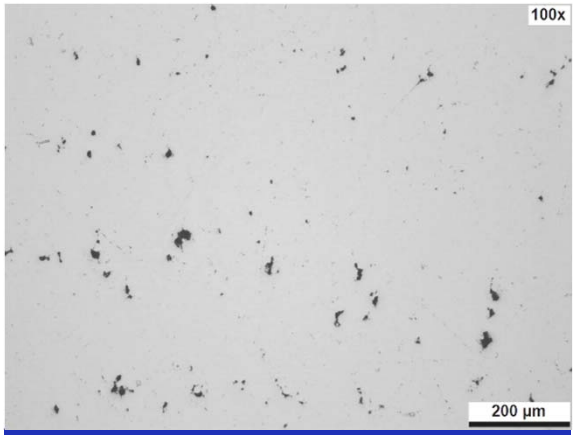
Source: MTU Aero Engines

Coating development

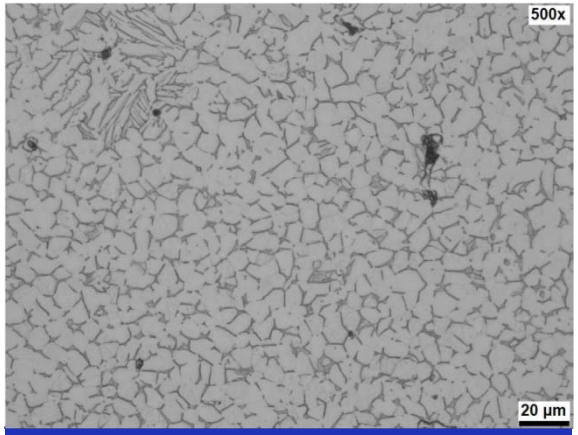
Ti6Al4V



Homogenize + Annealing



Homogenize + Annealing optimised



Homogenize + Annealing etched optimised

- Strength rises with lower porosity.
- Completely recrystallized microstructure can be see in the optimised coating after heat treatment.

Source: MTU Aero Engines

Summary

- We have a great opportunity to take this technology from its infancy into the future.

- Our industrialization competence should allow us to supply reliable equipment.

- Powders designed especially for cold spraying are under research.

- Improved performance will open new fields of applications:
  - Where high strength coatings are needed,
  - Where thick, oxidefree coatings are needed.