JOINING
INNOVATION
AND EXPERTISE

Cold Spray using Precipitation Hardenable Aluminium Alloys

Dr Henry Begg, TWI Ltd

Alexandre Sabard, University of Nottingham

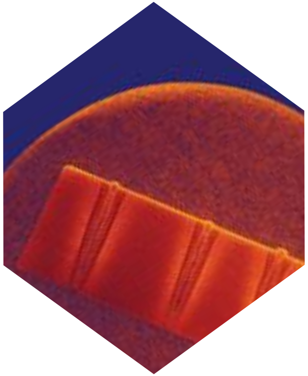
Introduction to TWI

- Membership-Based Research and Technology Organisation
- Established 1946
- Fabrication & Integrity of Materials & Structures
- Codes & Standards (>122)

- >800 staff + 50 students
- 700 Industrial Members in 4500 locations worldwide
- Regional Centres: UK & worldwide

TWI UK Offices

Introduction to TWI



WELDING, COATING & PROCESSING

Development of advanced welding / joining / forming / surfacing techniques.

STRUCTURAL INTEGRITY

Strategies to avoid failures
Experts in fatigue and fracture
Fitness-for-service assessments

NDT & ASSET RELIABILITY

Advanced expertise in non-destructive testing (NDT) and condition monitoring.

MATERIALS PROPERTIES

Microstructure-property relationships
Analysis and characterisation

SURFACE ENGINEERING AT TWI

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SECTION MANAGER

DAVE HARVEY
TECHNOLOGY FELLOW

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R&D MANAGER

MELISSA RILEY
PRINCIPAL PROJECT LEADER

PHIL MCNUTT
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BEN ROBINSON
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FRANCESCO FANICCHIA
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FEIFEI ZHANG
PROJECT LEADER

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PRINCIPAL TECHNICIAN

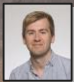
DAMIAN WHITEMAN
TECHNICIAN

ADAM MARKS
TECHNICIAN

ROSA GRINON ECHANIZ
STUDENT

MIKE WALKER
STUDENT

ALEX SABARD
STUDENT



CRAIG MELTON
STUDENT

BERENIKA SYREK-GERSTENKORN
STUDENT

Cover all topics relating to coatings, with particular focus on thermal and cold spray.

SURFACE ENGINEERING AT TWI

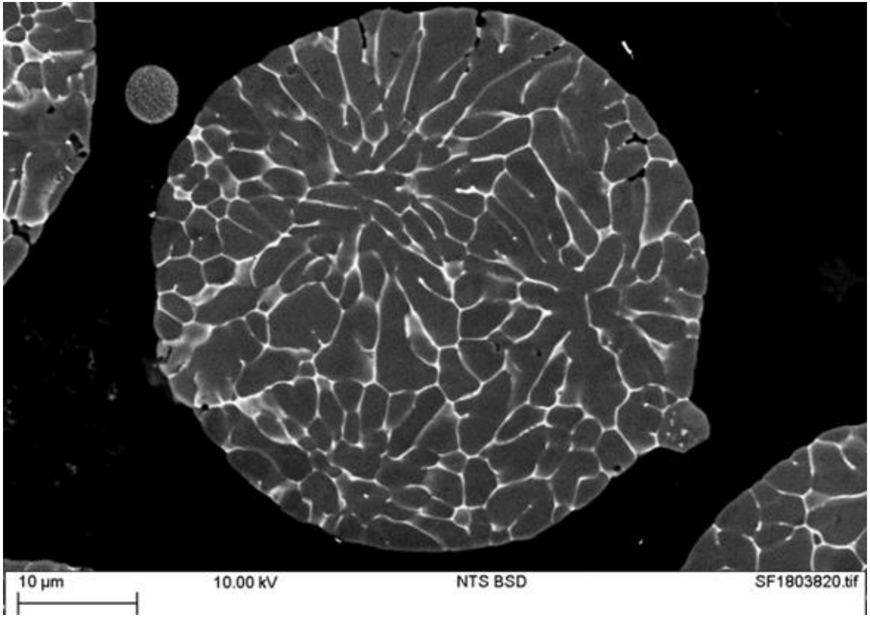
However, many other surface engineering related activities are researched at TWI

COLD SPRAY AT TWI

COLD SPRAY AT TWI

- TWO systems:
  - Impact Innovations 5/11
  - CGT Kinetix 4000
- Run primarily using nitrogen
- Large (7.5 x 6 x 4m) booth, with offline robotic integration

AA7075 POWDER



Aluminium alloys exhibit segregated, non-equilibrium, cellular dendritic structures when manufactured by gas atomising.

Not necessarily optimised for:

a) Cold spray deposition

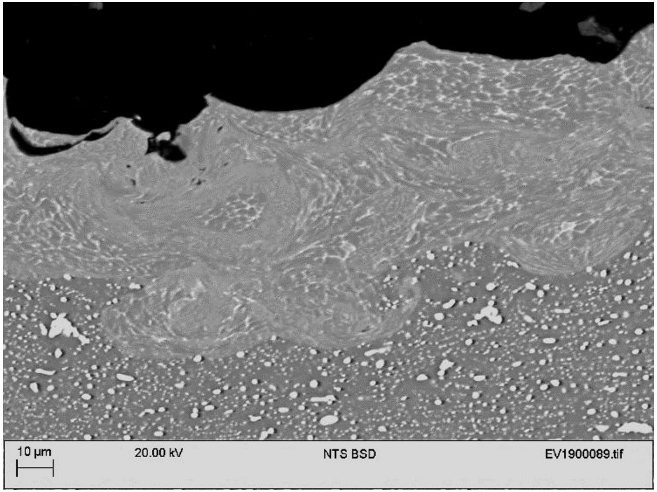
b) Final mechanical properties

COLD SPRAY OF AA7075

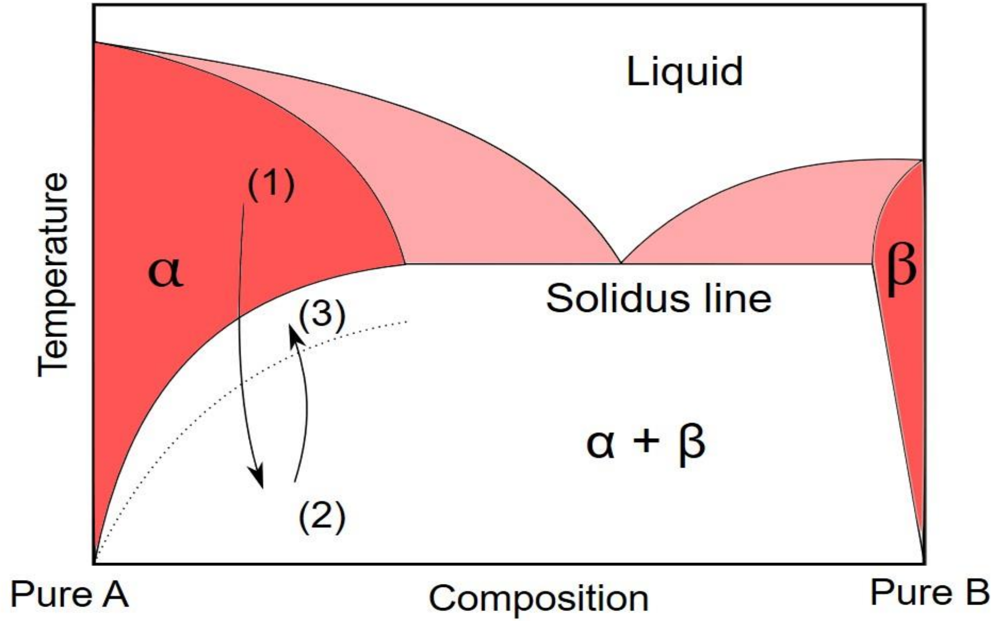
- When sprayed with N_2, does form a dense, well bonded microstructure.
- Segregation still evident.
- Very low deposit efficiency.

Deposit Efficiency (%)

Temperature, °C	Pressure, bar: 40	50	60
400	2.2	3.1	3.8
450	3.6	4.6	4.7
500	5.4	6.5	6.9

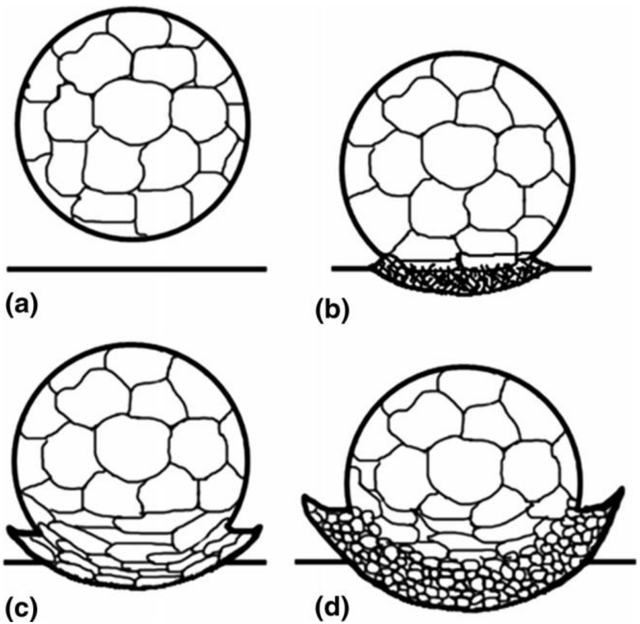


AA7075 HEAT TREATMENTS



Could we use more conventional heat treatment techniques and apply them to feedstock powder to improve deposition *and* resulting properties?

COLD SPRAY BONDING



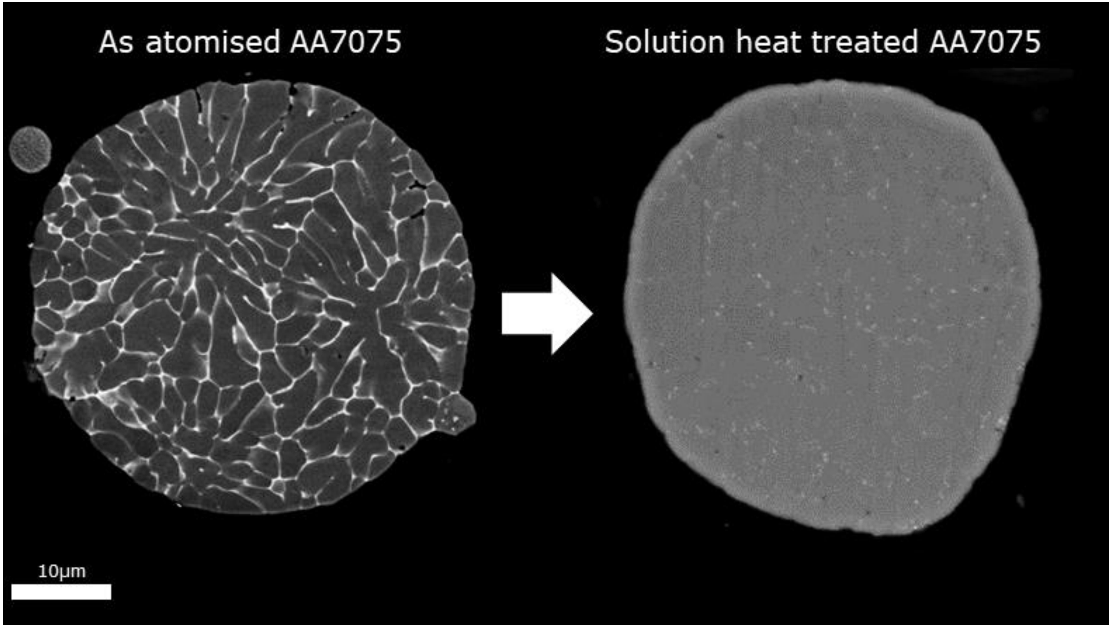
Likely to be much more complicated than

softer = easier to spray.

- Surface oxide effects
- High strain rates
- Recovery
- Recrystallisation

Rokni, M.R., Nutt, S.R., Widener, C.A., Champagne, V.K. and Hrabe, R.H., 2017. Review of relationship between particle deformation, coating microstructure, and properties in high-pressure cold spray. *Journal of Thermal Spray Technology*, 26(6), pp.1308-1355.

HEAT TREATMENT OF AA7075



Heat treated under Ar in a rotating vessel at 475°C for 1hr and then quenched.

COMPARING POWDER DEPOSITION

As atomised powder

Temperature, °C	Pressure, bar: 40	50	60
400	2.2	3.1	3.8
450	3.6	4.6	4.7
500	5.4	6.5	6.9

Solution heat treated powder

3x increase

Temperature, °C	Pressure, bar: 40	50	60
40[illegible]	[illegible].8	12	14
450	13	17	18
500	15	18	21

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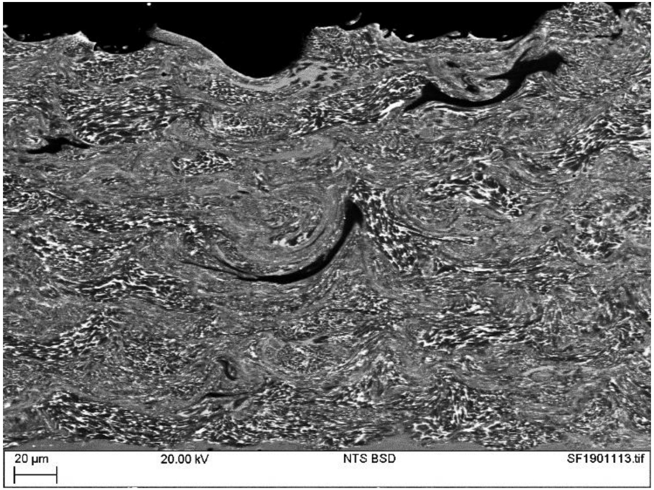
COMPARING POWDER DEPOSITION

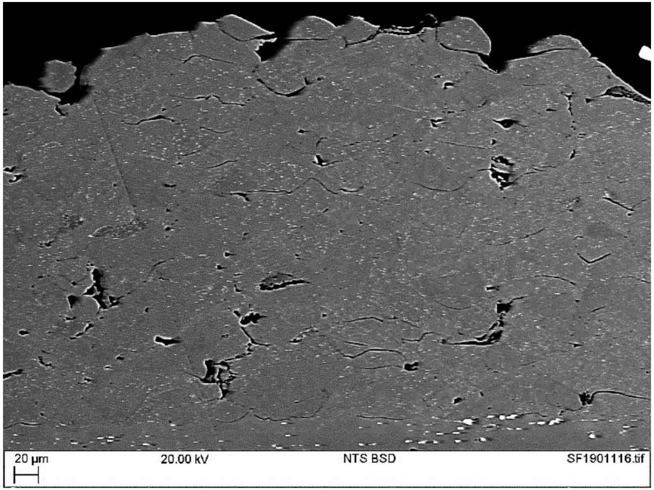
As atomised powder



60 passes

- High deformation
- Dense
- Clean interfaces

Solution heat treated powder

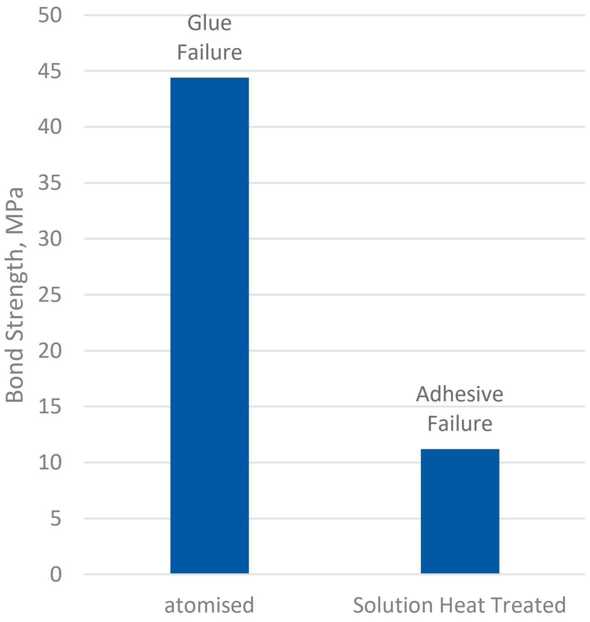


8 passes

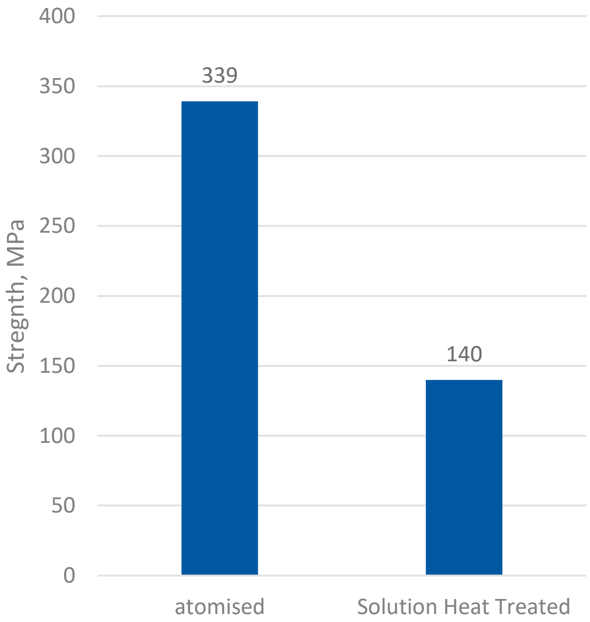
- High deformation
- Some porosity
- Some interfacial defects

COMPARING DEPOSIT PROPERTIES

Adhesion (ASTM C633)

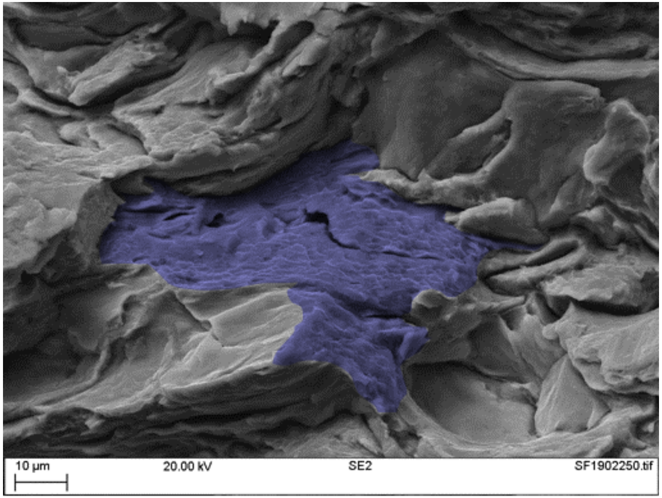


Cohesion (TCT)



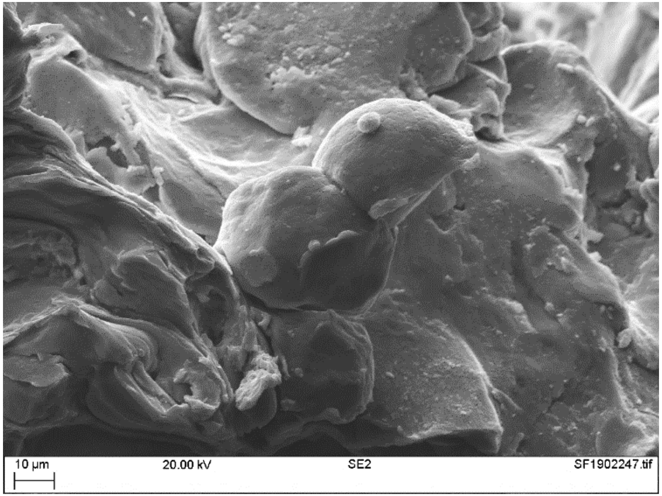
COMPARING DEPOSIT FRACTURE SURFACES

As atomised powder



- Evidence of ductile fracture.

Solution heat treated powder



- Decohesion between particles – little evidence of plastic deformation of individual splats.

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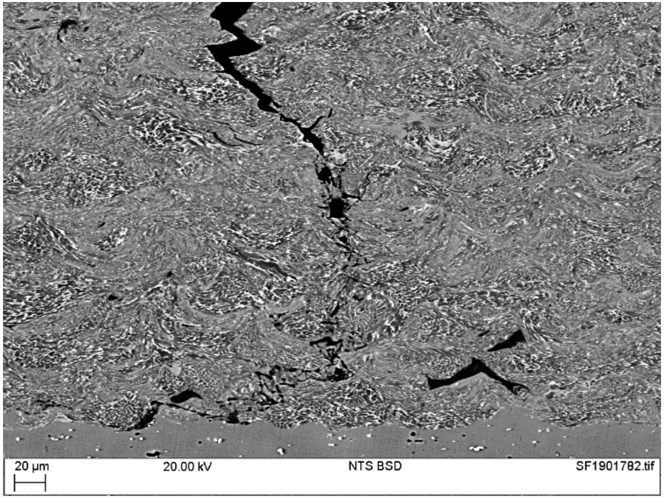
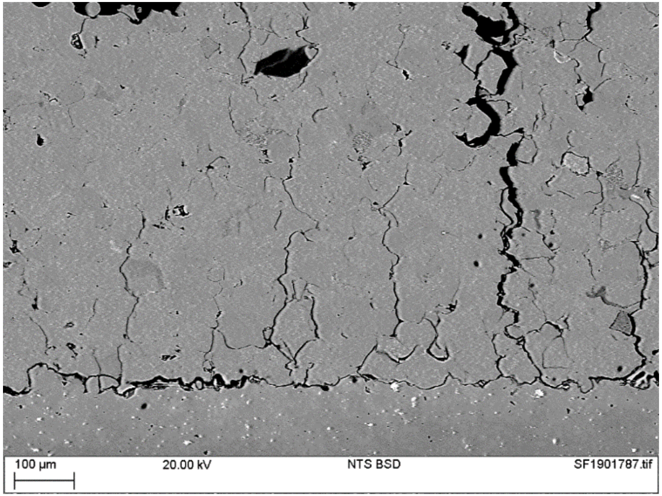
COMPARING DEPOSIT FRACTURE SURFACES

As atomised powder



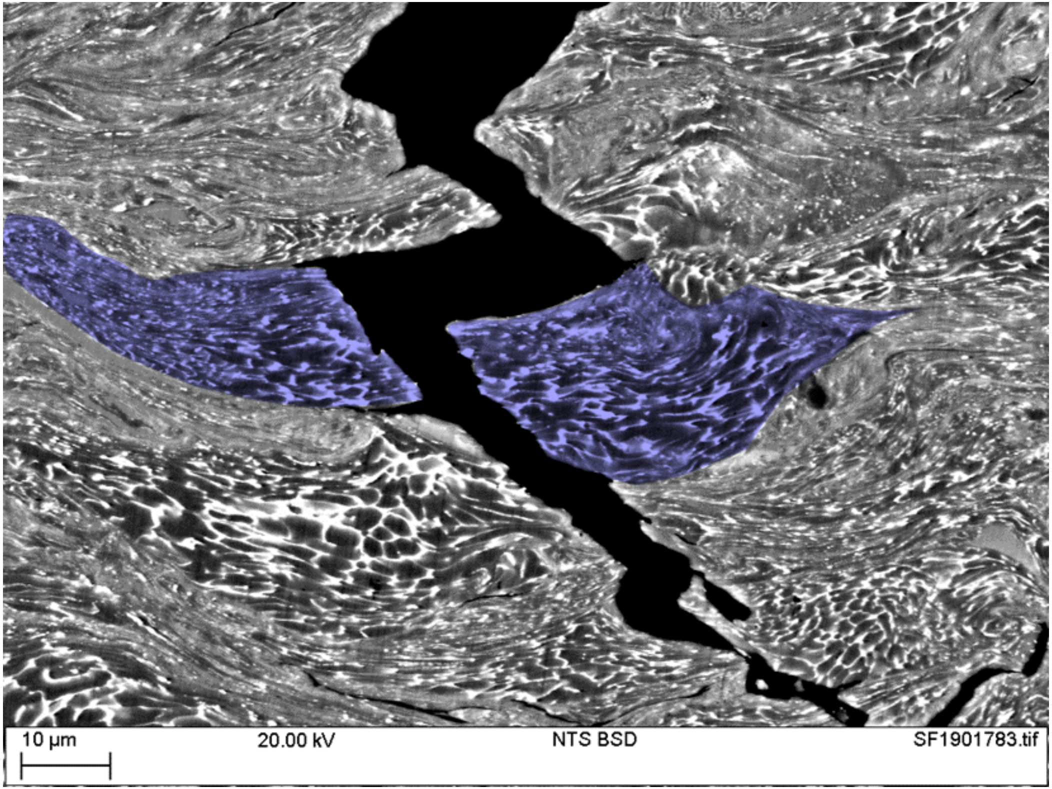
- Fracture through particles.
- Coating-substrate interface still bonded.

Solution heat treated powder



- Fracture follows particle boundaries.
- Coating-substrate interface coming apart.

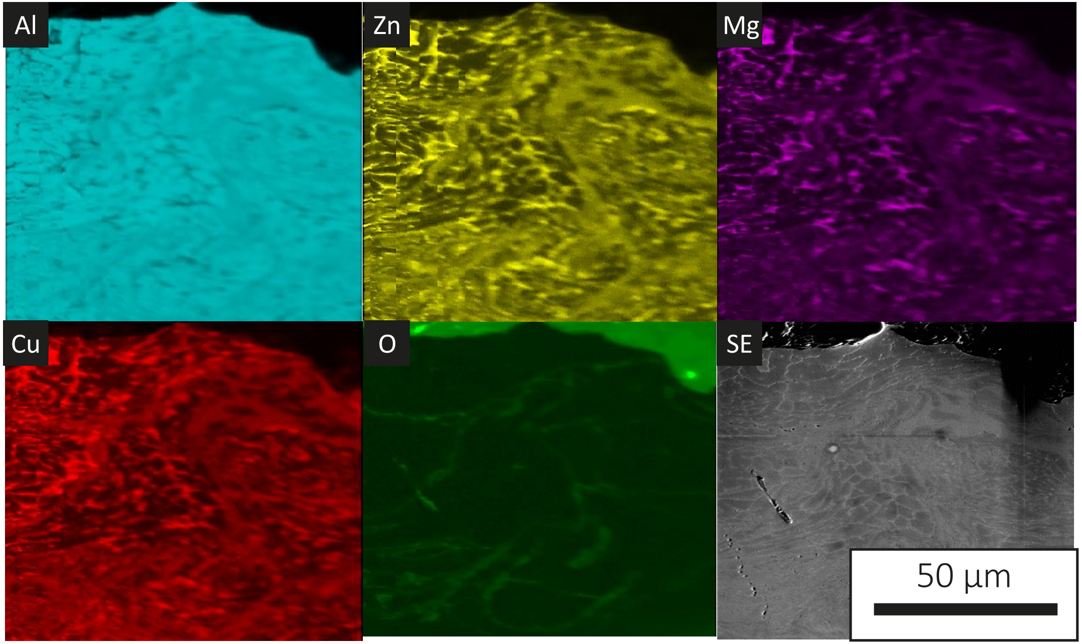
COMPARING DEPOSIT FRACTURE SURFACES



WHY HAS HEAT TREATMENT LOWERED PROPERTIES?

- Altered surface chemistry?

Atomised powder



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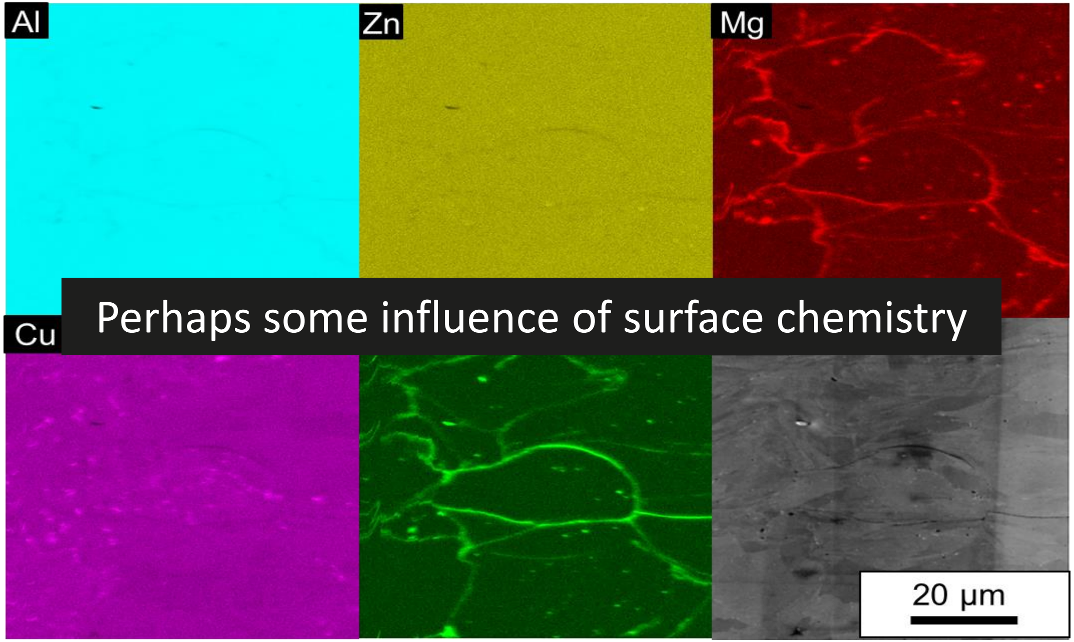
Solution heat treated powder



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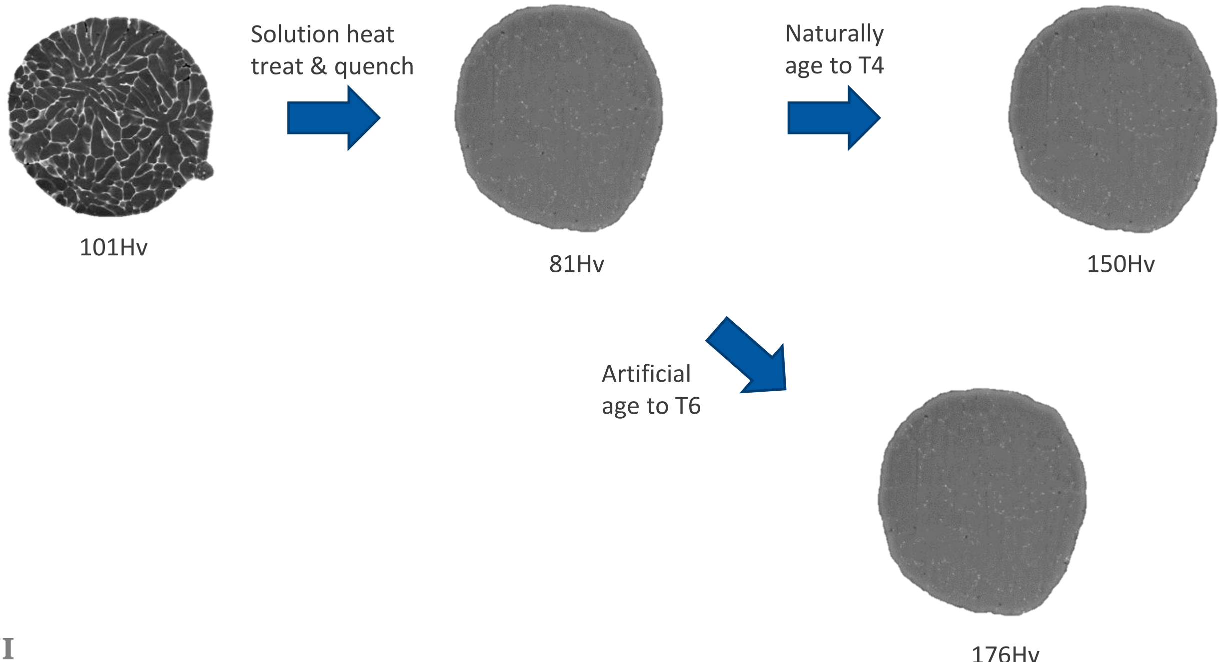
WHY HAS HEAT TREATMENT LOWERED PROPERTIES?

- Altered powder hardness?



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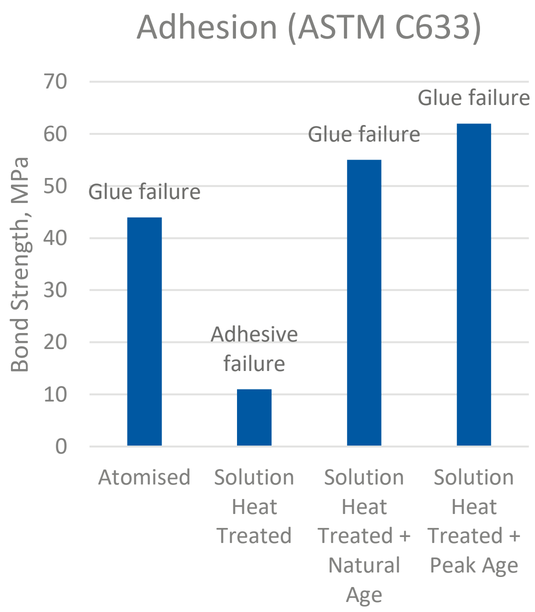

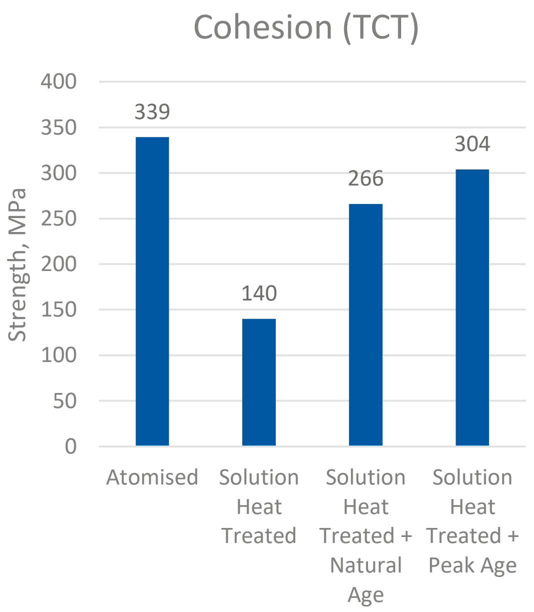

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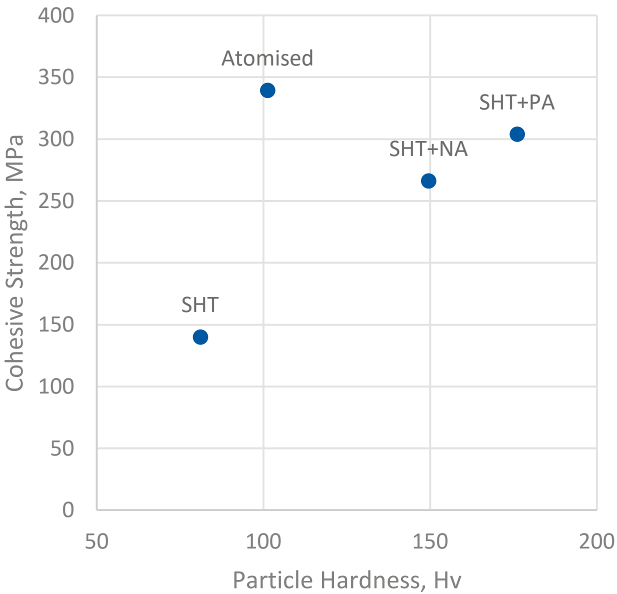
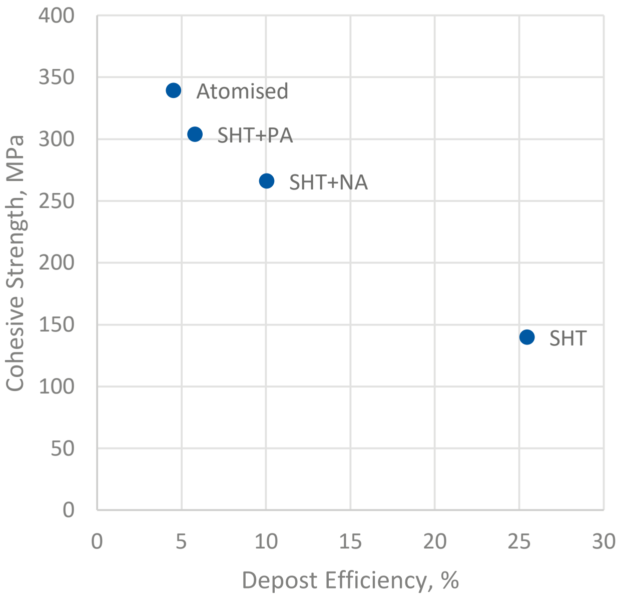


- Some correlation between powder particle hardness and cohesive strength.
- As atomised powder doesn't entirely fit this trend though.

WHY HAS HEAT TREATMENT LOWERED PROPERTIES?

- Altered powder hardness?



- Unfortunately, there seems to be a trade off between strength and deposit efficiency.

SUMMARY

- Powder heat treatment:
  - strong effect on how well particles deposit
  - strong effect on the mechanical properties of the deposit
- Mechanism
  - Surface chemistry?
  - Hardness effects and deformation behaviour?
- Is there any point in heat treating?
  - Certainly gains in deposit efficiency
  - Need for other properties? e.g. corrosion/SCC?
  - Further optimisation to gain the benefit of high D.E and high strength?

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PhD Opportunity

Repair of high-strength, corrosion resistant alloys using laser assisted cold spray

PhD Project Opportunity

Industrial Supervisor – Henry Begg (TWI)

Academic Supervisor – Tanvir Hussain (University of Nottingham)

Funding Body – Lloyd's Register Foundation (Fully funded)

Contact

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