Directional Dependency of Bulk Fracture Toughness in Cold-Sprayed Al 6061 Deposits

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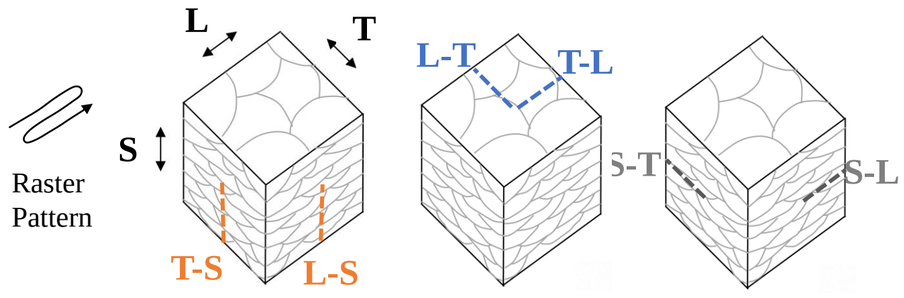
- Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the U.S. Government

Goal

Investigate the directional dependency of fracture toughness in cold spray deposits.

Method

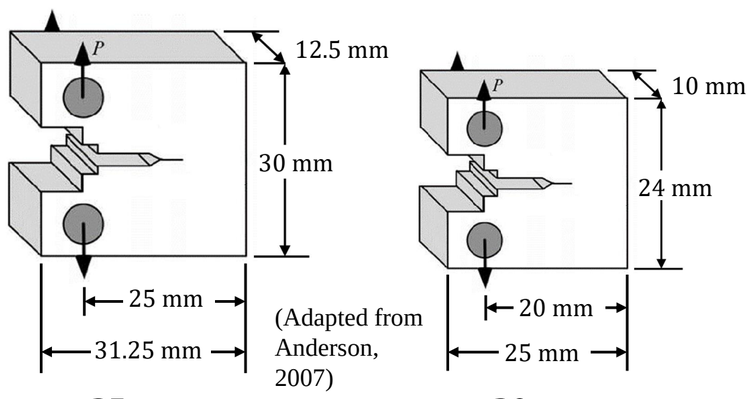
Crack Orientations



X: Parallel to rolling direction
Y: Transverse to rolling direction
Z: Through-thickness direction

L: Parallel to long rastering direction
T: Transverse to long rastering direction
S: Through-thickness direction

ASTM E399 - Compact Tension Specimen Geometry



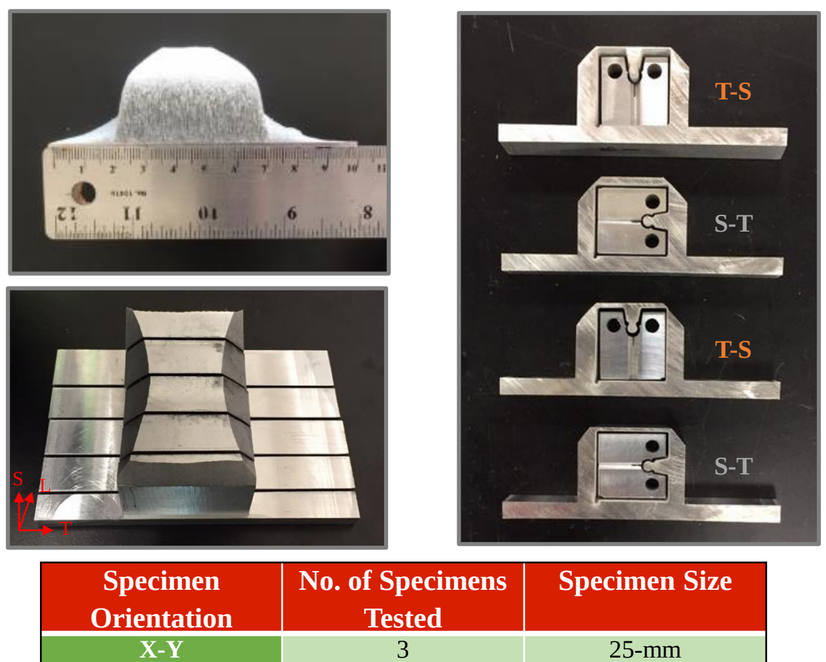
25-mm
X/Y-Y/X (WR)
CS L/T-T-L (CS)

20-mm
T/L-S (CS)
S-T/L (CS)

Spray Parameters

Spraying System	VRC® Gen III Max
Powder	Valimet® Al 6061, Mil-DTL-32495C, Amend. 2, 230-mesh
Substrate	Al 6061-T651, 6.35-mm (1/4-in.) Plate
Powder Feed Rate	6.1 g/min
Gas Type	Helium
Gas Pressure	3.5 MPa
Gas Temperature	400°C
Particle Velocity	1110 ± 160 m/s
Nozzle Material	polybenzimidazole (PBI)
Nozzle Model	VRC® Nozzle 0071
Nozzle Throat Length	2.7 mm
Nozzle Length	170 mm
Nozzle Throat Diameter	1.75 mm
Nozzle Exit Diameter	4.85 mm
Nozzle Standoff Distance	25.4 mm
Rastering Speed	254 mm/s
Rastering Step Size	1 mm

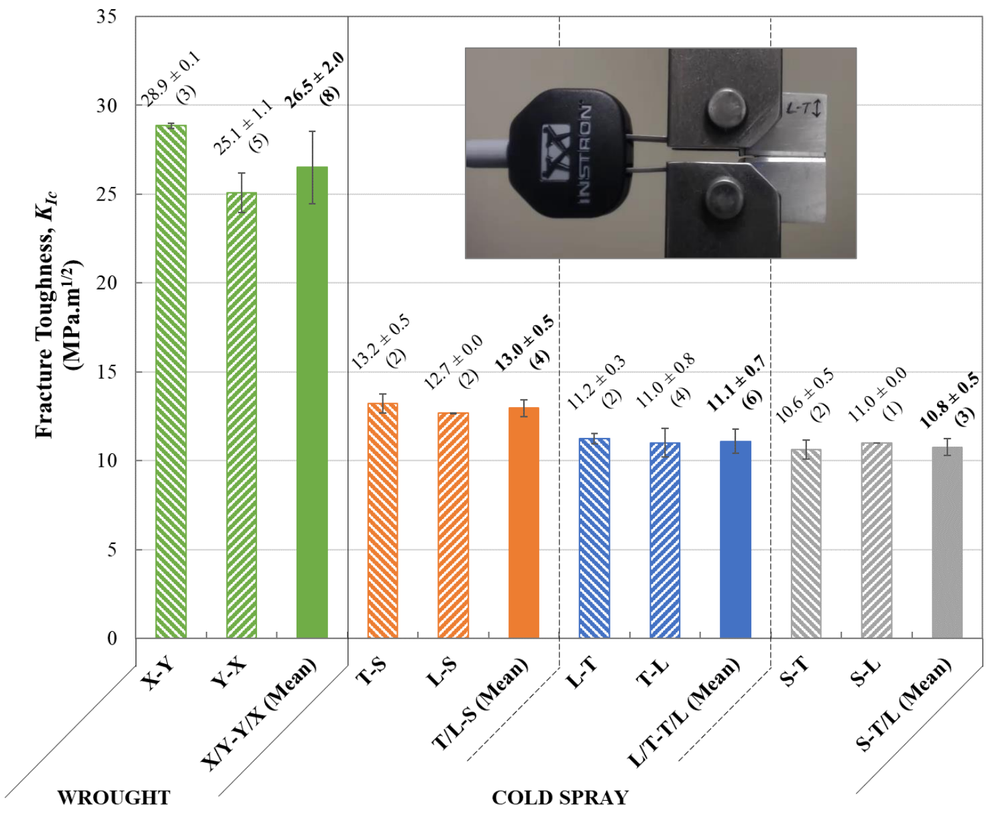
Specimen Fabrication



Specimen Orientation	No. of Specimens Tested	Specimen Size
X-Y	3	25-mm
Y-X	5	25-mm
T-S	2	20-mm
L-S	2	20-mm
L-T	2	25-mm
T-L	4	25-mm
S-T	2	20-mm
S-L	1	20-mm

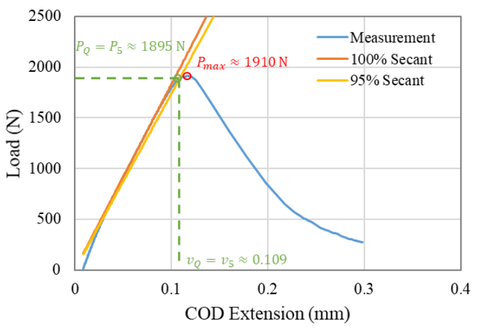
Results

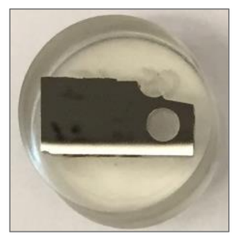
Fracture Toughness



Fatigue Pre-Cracking:
- 20 Hz at 60-80% K_{Ic}

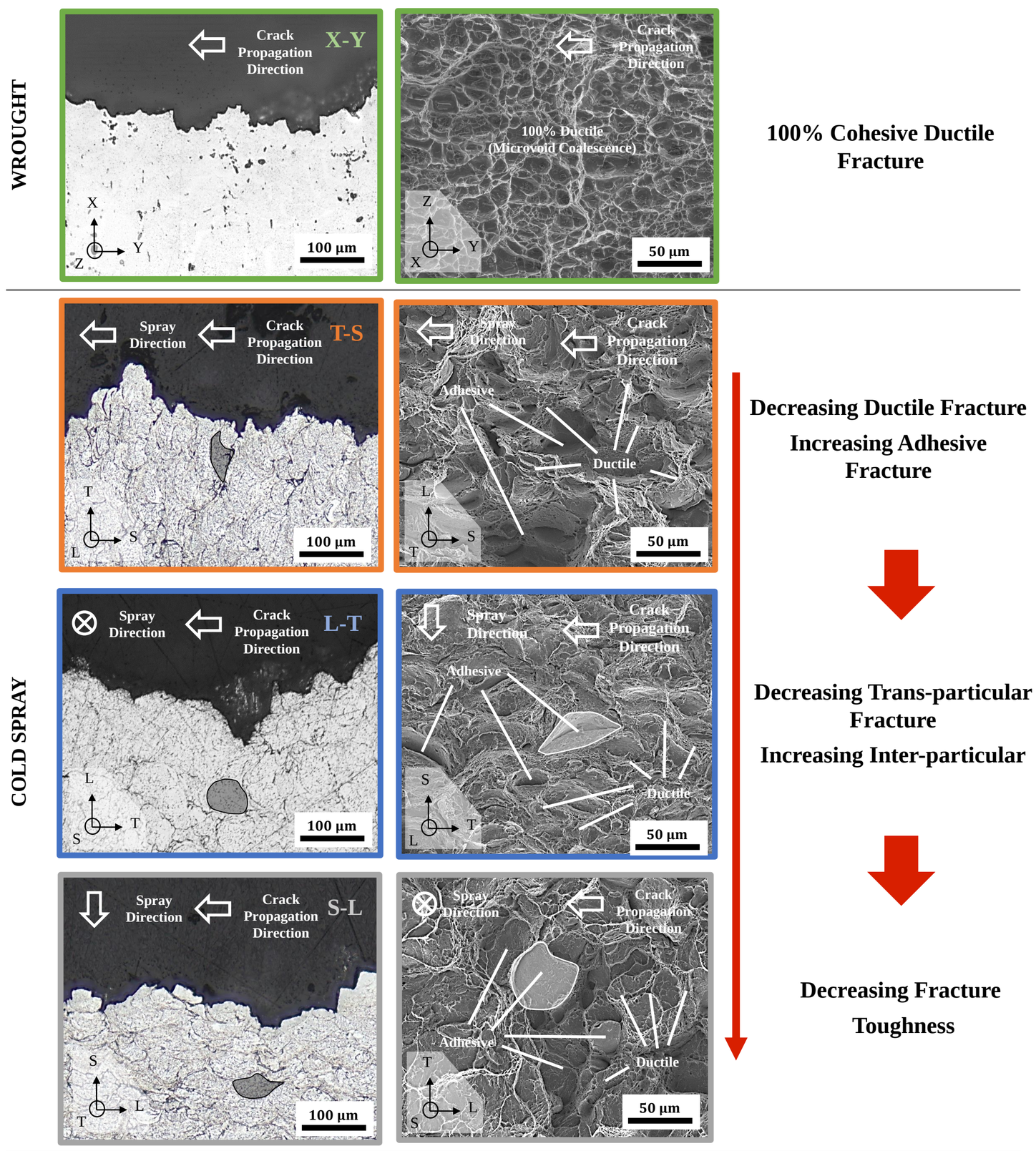
Fracture Testing:
- 0.65 mm/min crosshead control
- COD gage load-line displacement measurement
- K_{Ic} from 95% secant offset method




Optical Microscopy Specimen

SEM Specimen

Fractography



Conclusions

- **Fracture toughness is slightly higher in cold sprayed specimens when crack propagation is through the thickness.**
- **Cold spray specimens fail in a combination of trans-particular (cohesive ductile) and inter-particular (adhesive) modes, with the relative amounts depending upon crack orientation.**
- **Higher fracture toughness is correlated with a greater amount of trans-particular failure.**
- **Overall, cold spray toughness is approximately 40 – 50% that of wrought.**

Acknowledgements

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