



Massachusetts Materials Technologies LLC

Nondestructive Strength and Toughness Testing Applied to Cold Sprayed Aluminum 6061

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Massachusetts Materials Technologies LLC (MMT)

2014

Year company
founded

12

Employees
(6 Full-time
equivalent)

2

Non-Destructive
Testing (NDT)
technologies

1

Mission: Improve
safety globally
through cost-
effective NDT
technologies

Methods to Measure Metal Strength



Destructive Cut-Out



Nondestructive Portable Instrument



MMT's
Revolutionary
Technology



MMT's Nondestructive Portable Instrument

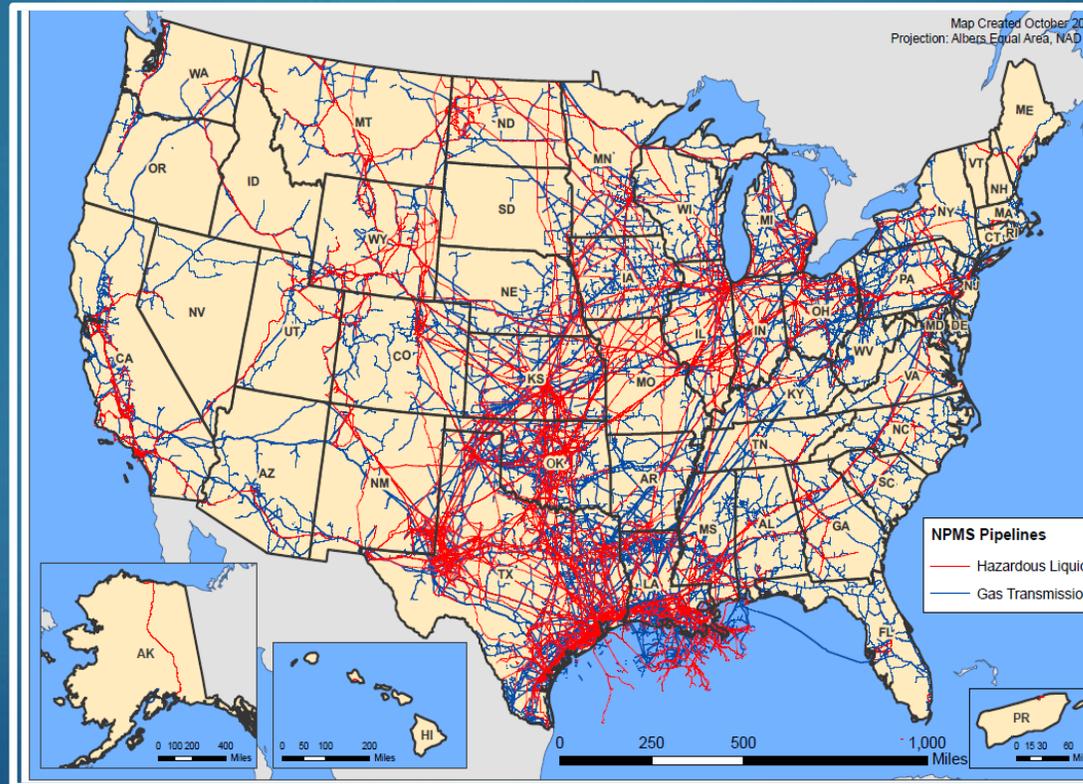
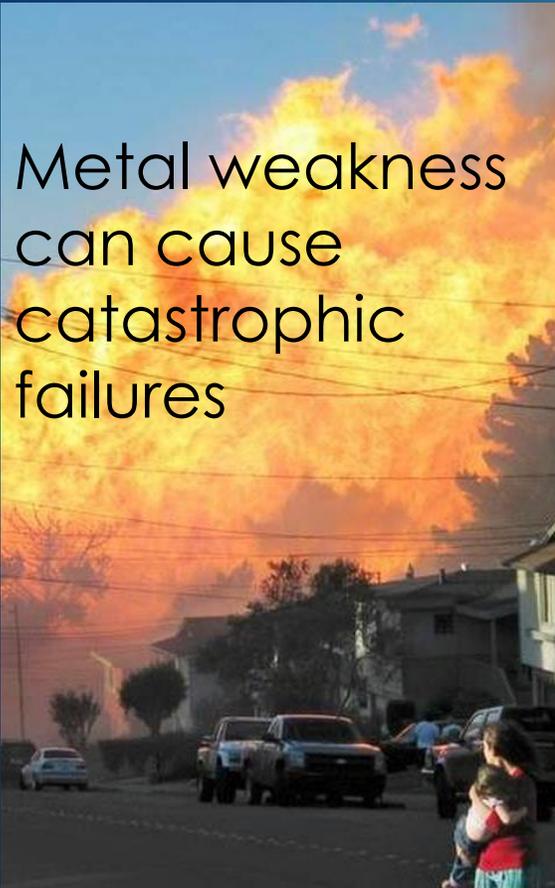
MMT Team at Your Service



Many structures are made of metal

- ▶ Pipelines
- ▶ Aircrafts
- ▶ Ships

Metal weakness can cause catastrophic failures



Other Nondestructive Applications



Energy • Defense • Aerospace • Infrastructure



Where materials and welding processes are relied upon for their strength and toughness.

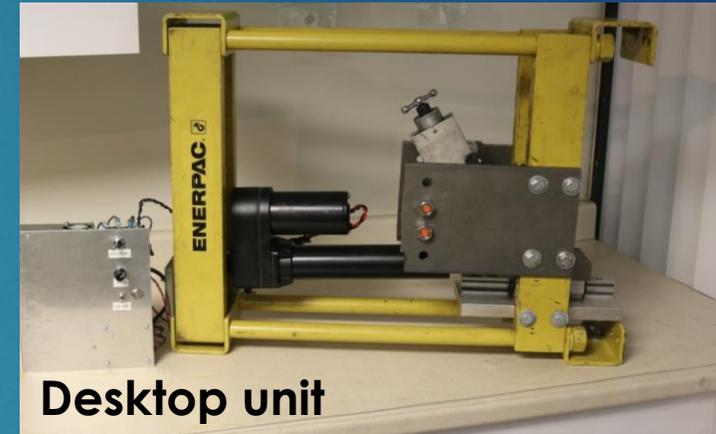
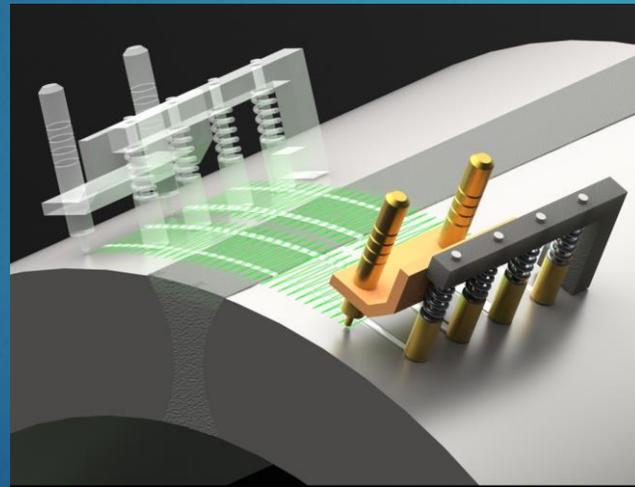
Two New Instruments for Nondestructive Testing

Hardness, Strength and Ductility (HSD)
(via frictional sliding)

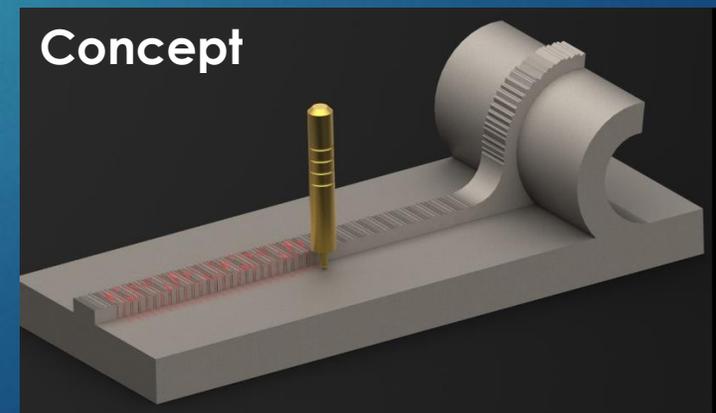
Fracture Toughness Tester (FTT)
(via micromachining)

Field unit on pipe

Concept on seam pipe



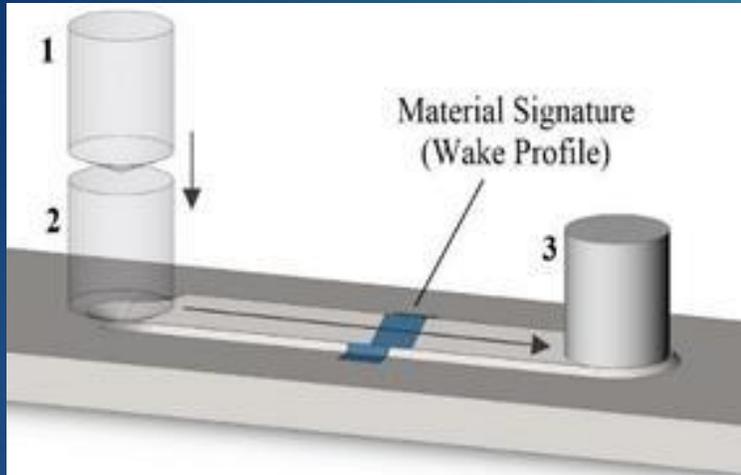
Desktop unit



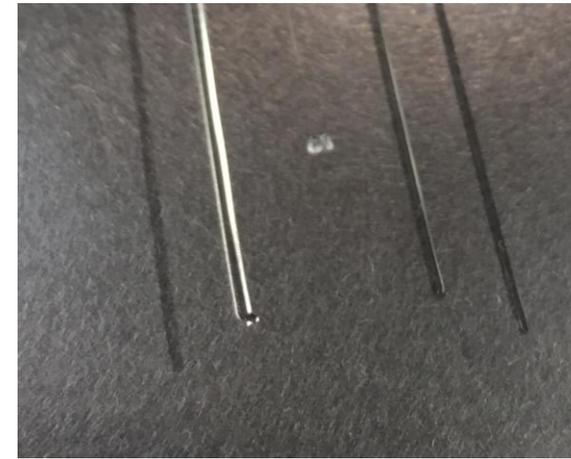
Concept

Innovative Breakthrough

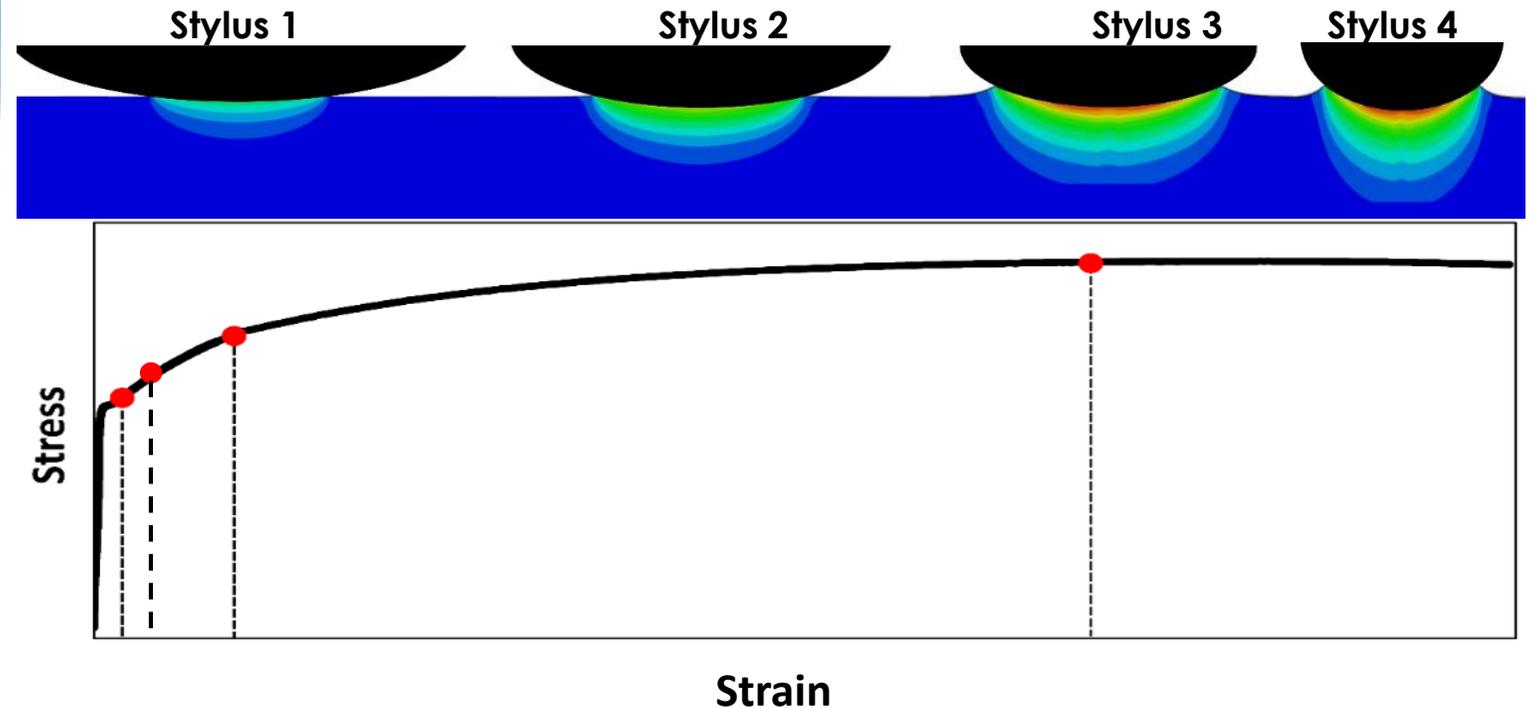
- ▶ Performs frictional sliding (instead of indentation)



- ▶ Technique supported by strong analytics – relationship with lab tensile test curve established (Bellemare PhD thesis, MIT, 2006)



*Superficial grooves
(less than 1 mil in depth)*



Validation Testing

“Direct measurement” of yield within 5% for material tested.

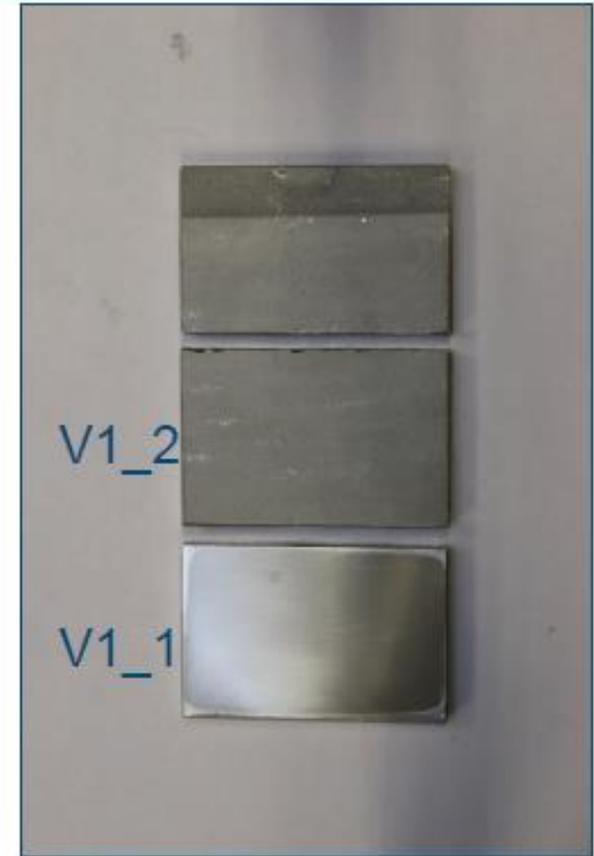
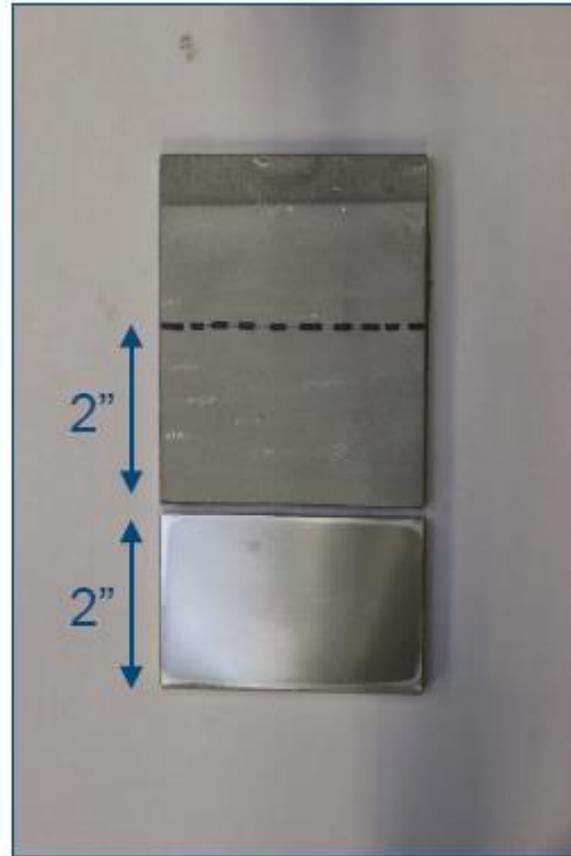
Sample	Type	Tensile Test 0.5% YS [ksi]			HSD Prediction 0.5% YS [ksi]			Range Error	Average Error
		Min.	Max.	Avg.	Test 1	Test 2	Avg.		
08T2	Midwall	34.4	40.3	37.0	38.3	35.8	37.0	0.0%	0.0%
F004	Flat	43.3	43.5	43.4	40.1	41.9	41.0	-5.3%	-5.6%
24T2	Midwall	43.4	44.5	44.0	45.8	46.7	46.2	3.9%	5.2%
12SLF	Midwall	43.3	47.7	45.5	46.0	45.9	46.0	0.0%	1.0%
14GRB	Midwall	42.8	51.7	47.3	50.7	48.0	49.4	0.0%	4.4%
12Y64	Midwall	49.4	50.5	50.3	51.8	50.3	51.1	1.1%	1.6%
18GRB-B	Midwall	50.6	53.7	52.2	51.5	52.0	51.8	0.0%	-0.8%
F001	Flat	53.5	54.0	53.8	53.8	55.5	54.6	1.1%	1.6%
16X42	Midwall	54.1	58.0	55.7	58.0	57.0	57.5	0.0%	3.2%
F015	Flat	56.1	56.9	56.5	59.8	58.5	59.1	3.9%	4.6%
10SHF	Midwall	64.1	66.0	65.0	60.8	63.0	61.9	-3.4%	-4.8%
16GRB	Midwall	69.8	70.2	70.0	72.1	69.9	71.0	1.1%	1.4%
F005	Flat	70.6	72.7	71.7	68.9	71.3	70.1	-0.7%	-2.2%
T3011	Midwall	72.5	73.0	72.7	69.6	70.0	69.8	-3.7%	-4.0%
F028A	Flat	53.8	55.8	54.8	52.1	52.8	52.5	-2.4%	-4.2%
F041	Flat	64.9	65.8	65.4	67.3	67.8	67.6	2.7%	3.4%
F030A	Flat	65.7	68.4	67.5	70.5	64.7	67.6	0.0%	0.1%

Aluminum 6061 Cold Sprayed

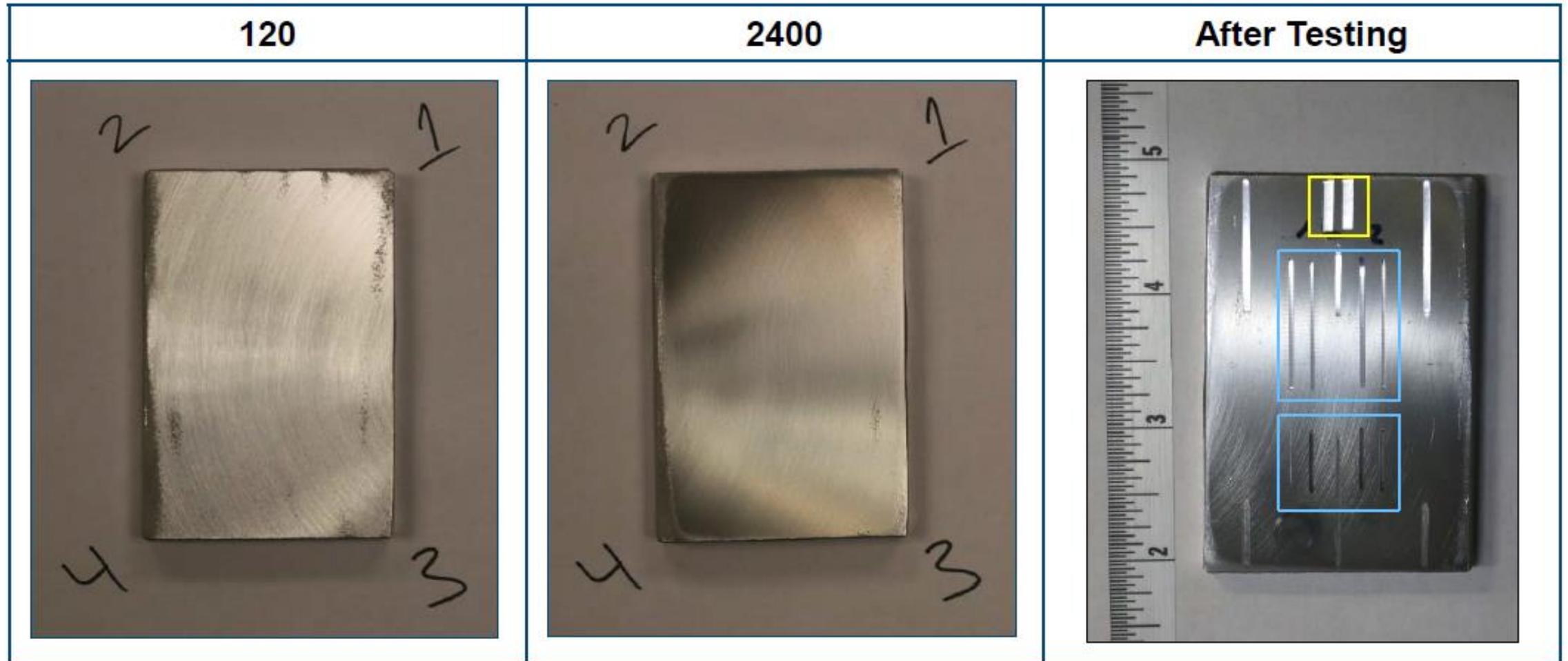
Sample V1



Cut 2" Test Pieces



Aluminum 6061 Cold Sprayed



■ FTT ■ HSD

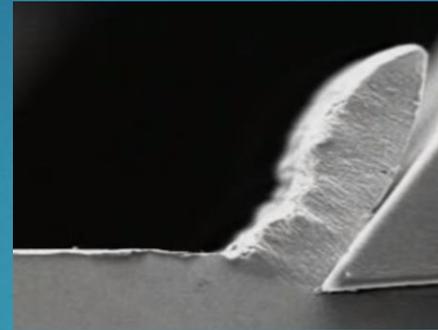
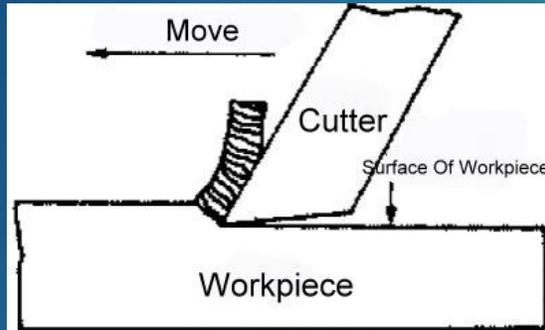
Aluminum 6061 Cold Sprayed (HSD blind test results)

Sample	Yield Strength EUL @ 0.5% [ksi]			Ultimate Tensile Strength [ksi]			Work Hardening Exponent			
	Test 1	Test 2	Average	Test 1	Test 2	Average	Test 1	Test 2	Average	
V1	36.8	36.0	36.4	38.9	42.5	40.7	0.043	0.087	0.065	Unprocessed
V3	29.3	30.0	29.7	39.6	41.0	40.3	0.130	0.134	0.132	Processed
W1	32.9	36.6	34.7	50.8	50.1	50.5	0.170	0.135	0.153	
W2	33.0	31.4	32.2	45.0	41.5	43.2	0.134	0.124	0.129	
M1	36.6	37.4	37.0	43.7	44.3	44.0	0.091	0.088	0.090	
M2	37.4	38.7	38.1	37.4	46.5	42.0	0.128	0.092	0.110	Unprocessed
M3	43.8	–	43.8	43.9	–	43.9	0.001	–	0.001	
M4	36.5	–	36.5	46.7	–	46.7	0.236	–	0.236	Processed

V3 (UTRC) expected SY **33.8 ksi** & UTS **40.5 ksi**

MMT's Fracture Toughness Tester (FTT)

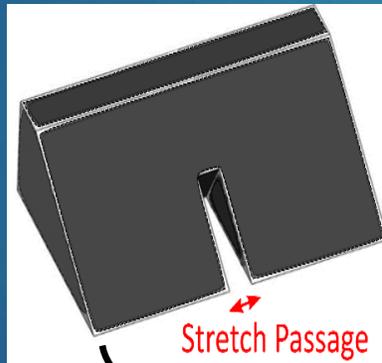
Started from Machining Process:



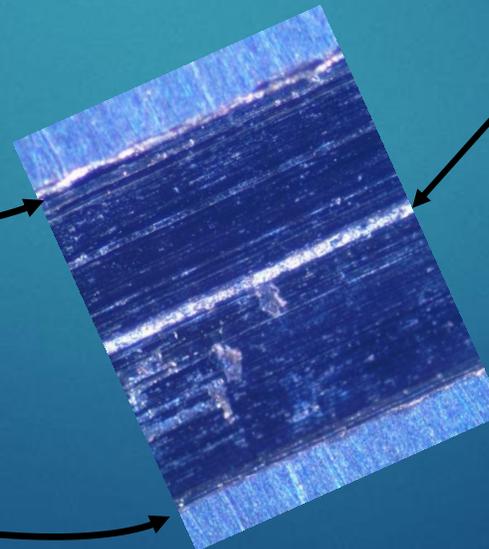
Traditional machining removes a layer of material through (predominantly) shear fracture

MMT's revolutionary concept:

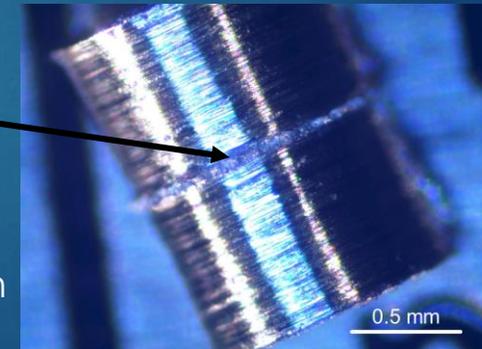
FTT Wedge Stylus



Machines off a thin (2-3 mil) layer



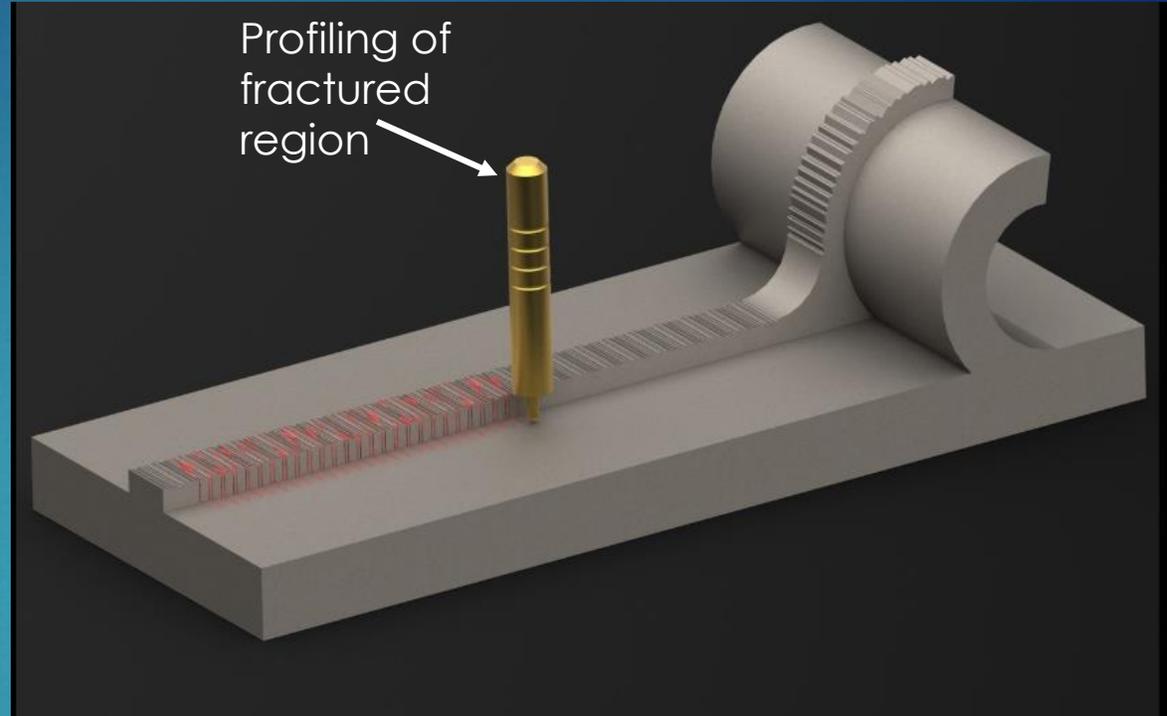
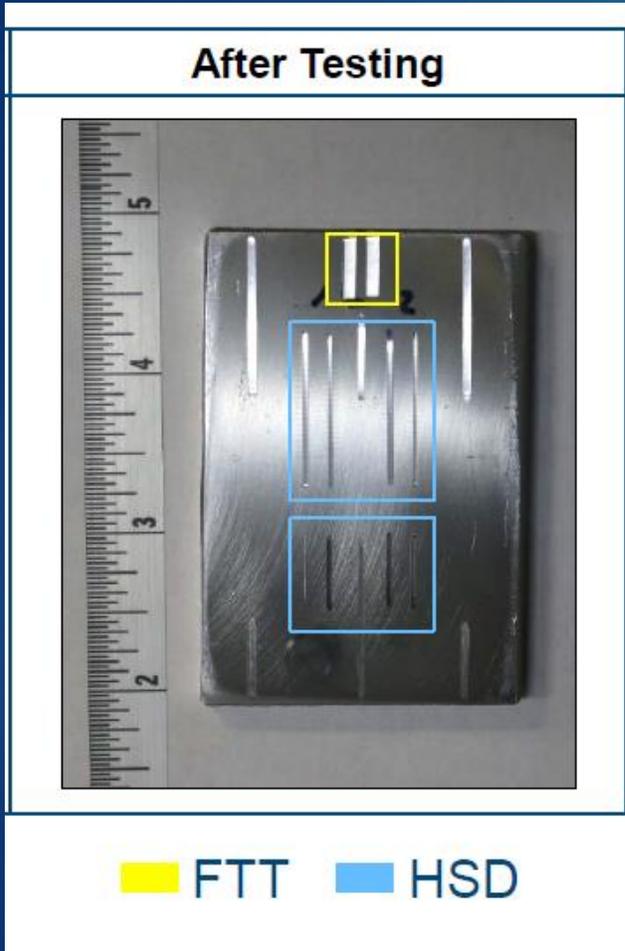
Machined chip



The center area is the fracture surface region

MMT's FTT generates and probe the fracture energy in crack-like stress field.

Aluminum 6061 Cold Sprayed



Sample	Max. Ligament Height [μm]			
	Test 1	Test 2	Test 3	Avg.
V1	18.7	18.8	14.9	17.5
V3	23.8	37.7	34.2	31.9
% Difference (V1/V3)				-45.2%

Potential Steps Forward

Determine what is really needed – input / discussion

- ▶ Improve sample preparation / tool geometry for specific applications
- ▶ More lab sample validation
- ▶ Extend to specific needs as most appropriate (bond strength?)

MMT

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