Advanced Energy Conference 2018

27 March 2018

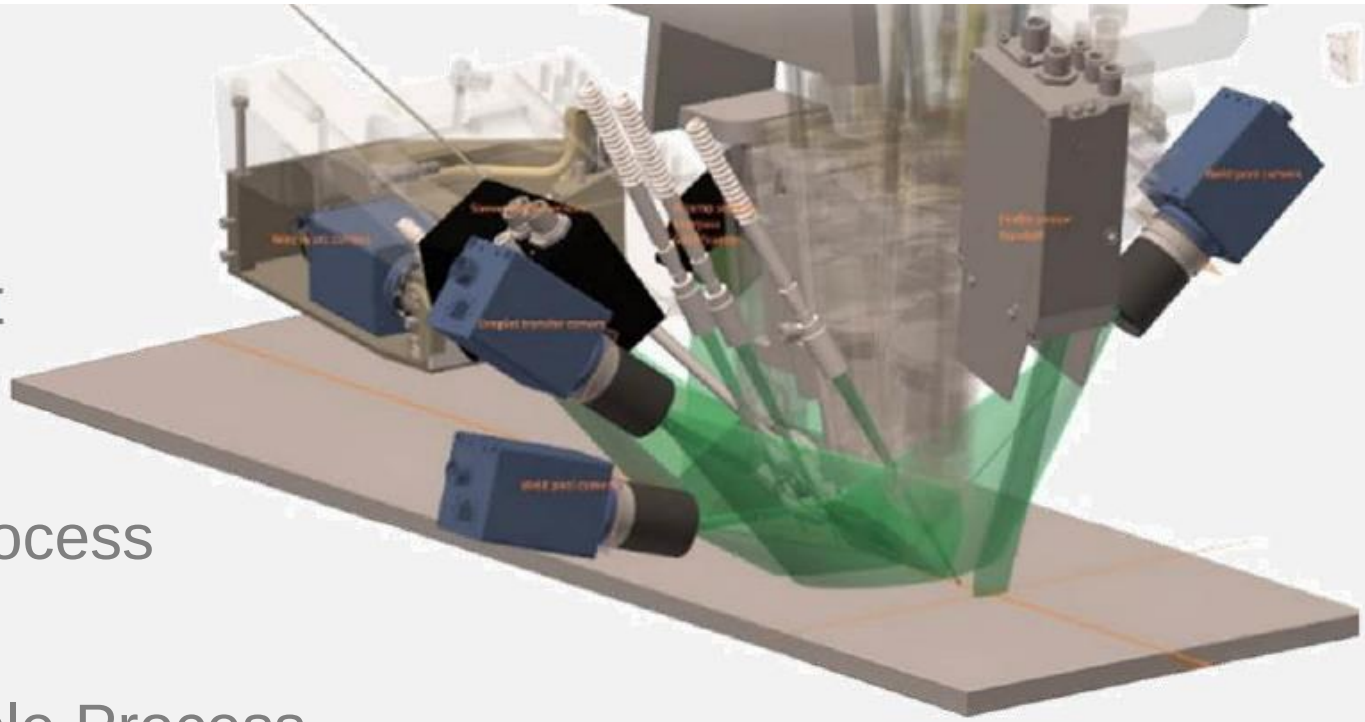
NORSK TITANIUM

Norsk Titanium History

- 2007 – Norsk Titanium AS Established
- 2013 – AS9100C Certified
- 2015 – First Merke-IV Production Machine
- 2015 – Investment by New York State
- 2016 – OEM Qualified Producers List
- 2017 – Printed Inconel 718
- 2017 – First Production Order
- 2017 – AS9100D Certified
- 2017 – Norsk/Boeing team Receives Aviation Week Laureate Award
- 2017 – 20 Machines Delivered to New York
- 2018 – Plattsburgh Facility AS9100D Certified
- 2018 – Plattsburgh Facility added to OEM Qualified Producers List
- 2018 – First Production in Plattsburgh

Norsk Titanium's Wire Based Additive Process

- Titanium Wire
  - High Rate Deposition
  - 5-10kg per Hour
- Argon Environment
  - No Vacuum
  - Metallurgical Quenching



- 2 Torch Plasma Process
  - Workpiece Preheating
  - Workpiece Layer Fusion
- Repeatable/Scalable Process
  - Demonstrated Repeatability over Time
  - Demonstrated Repeatability Machine to Machine

Qualified Rapid Plasma Deposition (RPD™) Process

Process Scalability

Design of Experiment

- Purpose: Validate/Establish that the range
  process envelope produce acceptable mat
- Methodology: Perform combinations of K
  limits, influence and interactions for each
  - Statistical approach, based on central comp
  - Center values, representing nominal values
  - Cube values, representing normal process
  - Axial values, representing extremes/bounda
- Six factors (primary KPP's) identified

Factor	-Axial -α	-Cube -1	Ce
1. Interpass Temp (C)			
2. Stand Off Dist (mm)			
3. Melter Torch Plasma Gas (l/min)			
4. Plasma Transfer Arc (A)			
5. Wire Feed Rate (m/min)			
6. Traverse Speed (mm/s)			

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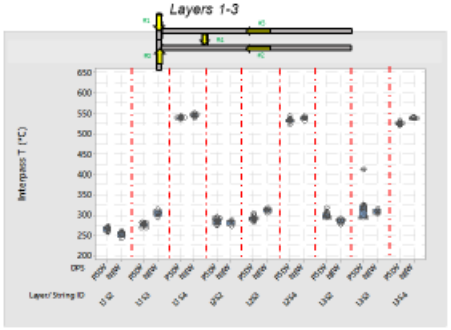
Part Repeatability

Purpose and Objective

- Collect, analyze, compare and summarize proc
  same part; by string; by layer



Variability Controlled over Time through to

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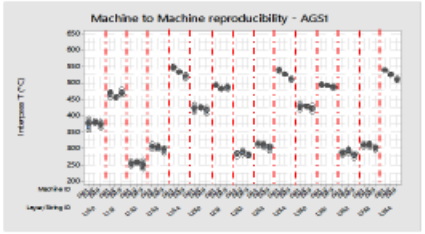
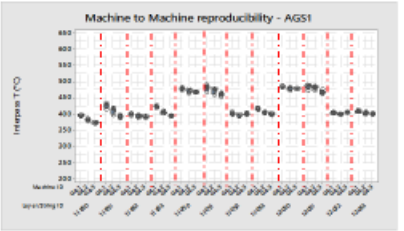
Machine to Machine Repeatability

Purpose and Objective

- Collect, analyze, compare and summarize process data acquired during "production readiness AGS" campaign among the three machines





Effective Calibration Techniques Ensure Consistent Quality over time and across machines

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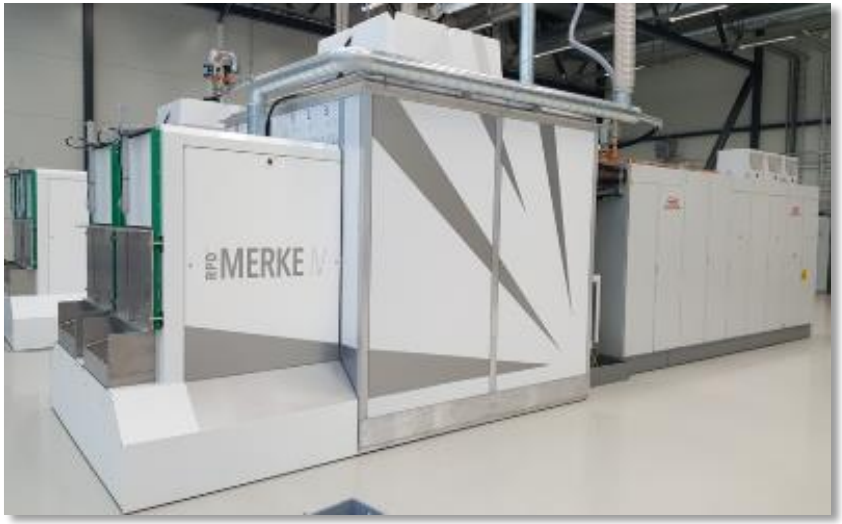
Material Focused Process

Tensile Properties

X	Sample Minimum	Sample Maximum	A(T99)	B(T90)	S
F_{tu} *Ultimate Tensile Strength* Ksi	133.3	146.5	133	136	
F_{ty} Yield *Tensile Strength* Ksi	119.5	133.4	119	122	
Elongation (%)	6.5	24			6

Z	Sample Minimum	Sample Maximum	A(T99)	B(T90)	S
F_{tu} *Ultimate Tensile Strength* Ksi	127.6	148.2	128.5	130.5	
F_{ty} Yield *Tensile Strength* Ksi	116.7	136.5	116	118	
Elongation (%)	8	28			6.2



Reference AMS 4911	
UTS	130 Ksi
YTS	120 Ksi

Norsk Titanium Facilities

Plattsburgh, New York, USA

Production Center

- 21 Machines Delivered
- 9 Machines Installed
- 11More to Deliver
- Part Development
- Part Production

Hønefoss, Norway

Technology Center

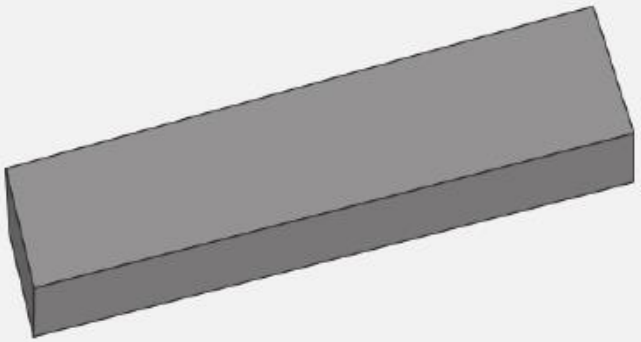
- 3 Machines Operating
- Part Production
- Primary Technology Development Site
- Part Production

Machine Production Center

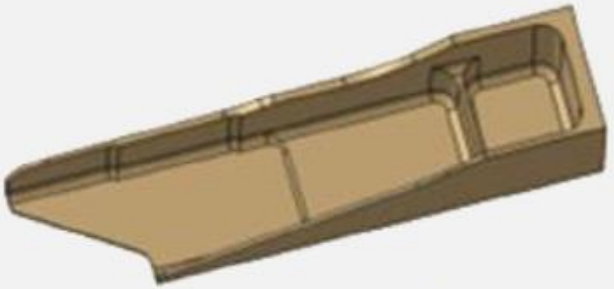
- Machine Production Line

Additive Manufacturing Value Equation

- Typical Structural Aircraft Part
  - 1.9kg Finished Weight
  - 15.0kg Block Starting Weight (8:1 BTF)
- Reduced Use of Titanium
  - RPD™ Weight 4.8kg (2.5 BTF)
  - 68% Improvement in BTF
- Reduced Machining
  - Remove 2.9kg vs 13.1kg of Titanium
  - Removal Costs - $75/kg/hr to $100/kg/hr



Legacy 15kg Block of Titanium



Finished Part – 4.8kg RPD™

60% Buy to Fly Improvement

Energy Savings

- The efficiencies of NTi's Additive Rapid Plasma Deposition™ process result in significant savings
- This year, for example, Plattsburgh's machines operating at predicted demand, could save about 570 tons of titanium
  - Which would have required 12GWh to produce
- At full production, the Plattsburgh facility, with 32 machines, can save 1,500 tons of titanium annually
  - This results in 33 GWh total savings annually, enough to power almost 5000 New York households

60% Buy to Fly Improvement = Large Energy Savings

The Potential

- ~ 25-35% Reduction in Ti64 costs
- ~ 60% Savings in material waste
- Significant total engergy savings over traditional manufacturing requirements