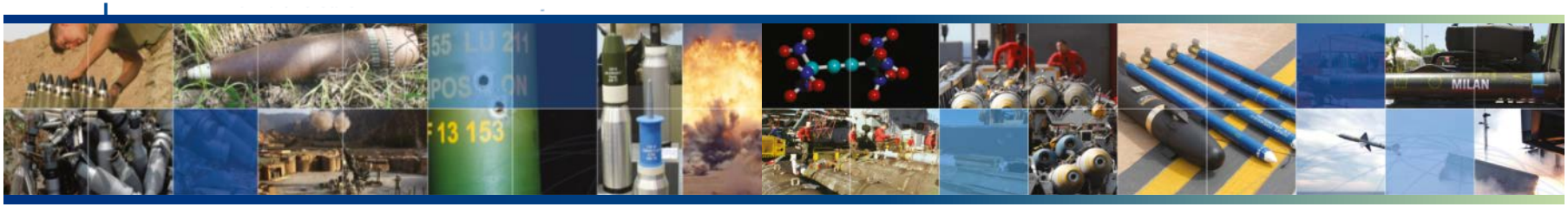
MSIAC

Munitions Safety Information Analysis Center

Supporting Member Nations in the Enhancement of their Munitions Life Cycle Safety



Property-Processing Implications in Additive Manufactured Materials for Munitions

An MSIAC Limited Report

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Supporting Munitions Safety

MSIAC OBJECTIVES

- A 2017/18 Work Element:
  - Novel Material Flaws & Processing/Property Implications of Additive Manufacturing (AM) for Energetics

- AM is being applied in energetics / munitions
- Unique processing creates novel flaws and failure modes
  - Heating, melting, re-melting, powder deposition, incomplete melting, extrusion/flow, curing, etc.
- Material selection in AM is still nascent
  - Availability, melting, processing

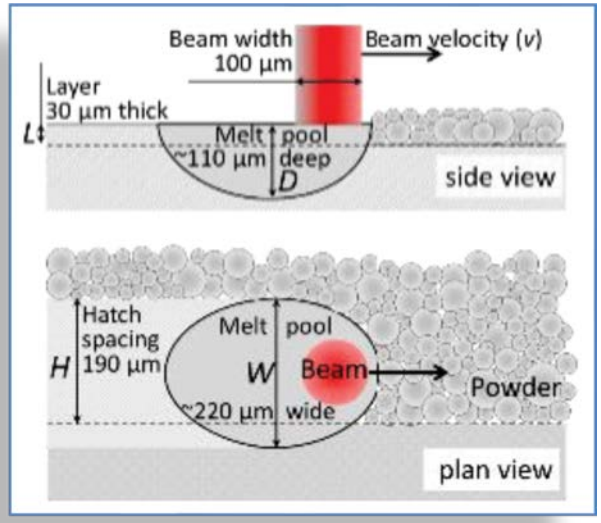
AM FOR MUNITIONS

- Process rigidity has been a hallmark of energetics processing
  - Safety, repeatability: driving forces
  - Once a process is qualified, adhere to it!

- Flexibility is the primary virtue of AM
  - Ability to fabricate virtually any part
  - Variability from one part to the next
  - Compositional variation within a part…

AM VARIABILITY

- Variability at all levels
  - Within one build
    - Location and geometry dependent
  - Between multiple builds
    - Same machine, same settings
    - Same machine, varied settings
    - Different machines, same manufacturer
    - Similar machines, different manufacturers
    - Different users…

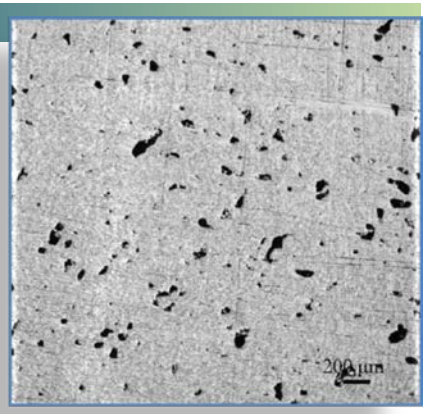


Presented by Tang, Carnegie Mellon U., in "Overview of Materials Qualification Needs of Metal Additive Manufacturing." M. Seifi, A. Salem, J. Beuth, O. Harrysson, J. Lewandowski, JOM 68(2016)

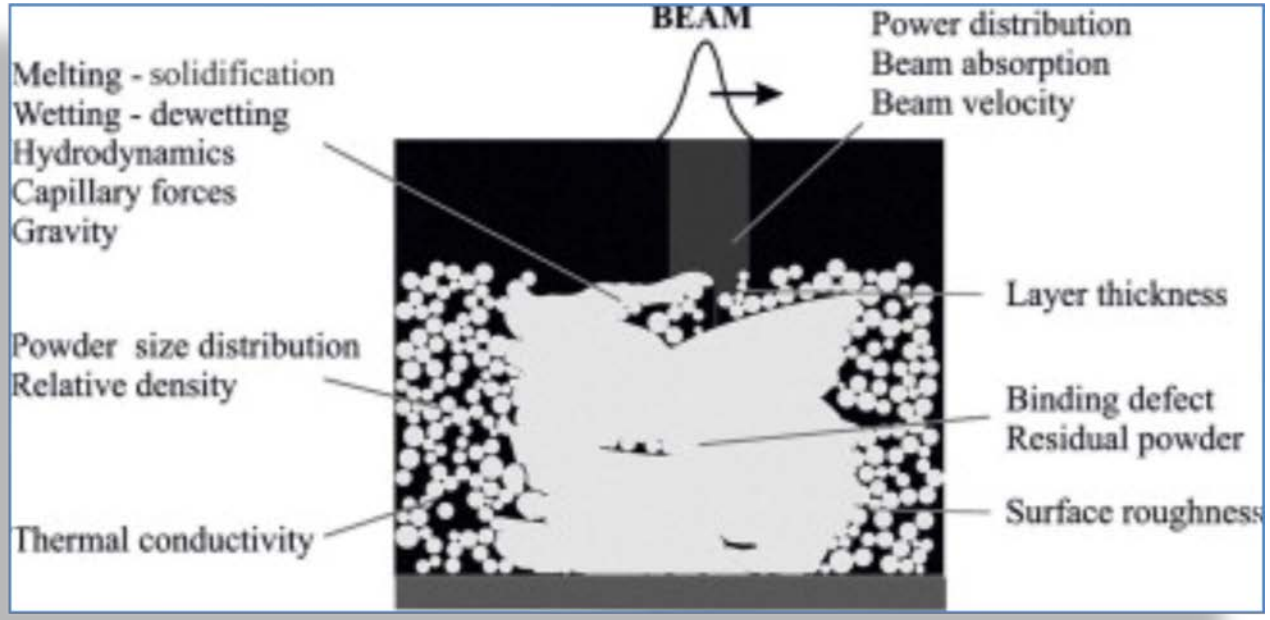
Defect Discovery

- Novel defects are being discovered
  - New processing methods bring new defects, flaws, failure modes
- Defects vary between processing methods
  - Need to match, catalog, and quantify
- Classical discovery of defects is through failure
  - Modern society seems to have a lower threshold for technical failure

Types of Defects



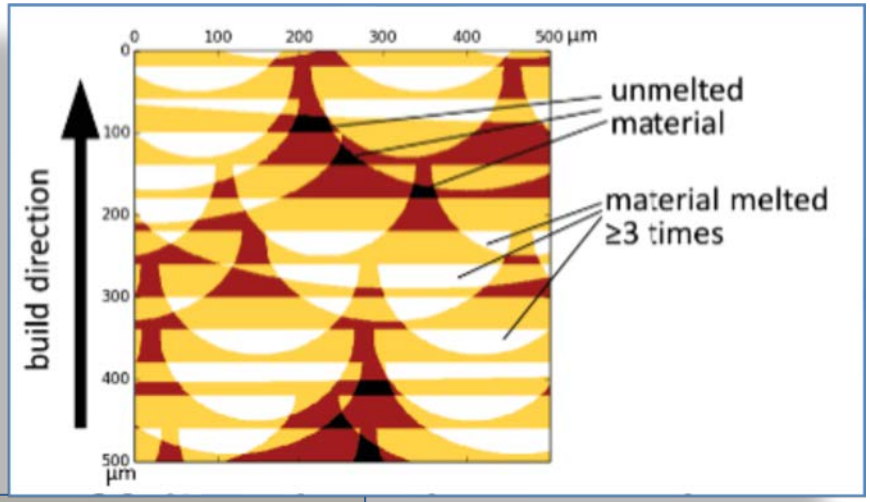
- Porosity
- Voids
- Layer / Cross-layer Defects
- Under-melted / Under-consolidated
- Cracking
- Surface Finish



"Defect Generation and Propagation Mechanism During Additive manufacturing by Selective Beam Melting." Bauereiss, A., Scharowsky, T., & Korner, C., Journal of Materials Processing Technology Vol. 214 Iss. 11 (2014)

PSPP INTER-RELATION

- Processing, structure, properties, & performance are intimately linked
- Classical understanding arrived at through decades, centuries of experimentation
- Nascent AM techniques are not well-understood with respect to PSPP



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Implementation Challenges

- Fabricating replacement parts
  - Classical parts are qualified via statistical analysis, process controls, inspection
- AM Characteristics
  - Continually variable, local processing
  - Raw materials intended for radically different processing methods
  - Flexibility is a disadvantage – unconstrained process
  - Ability to create difficult–to–inspect geometries
  - Fab process may introduce heating and reheating
  - As-yet-difficult to establish post processing treatments

PARALLEL INDUSTRY KNOWLEDGE

- Airframe manufacturers
  - Certify AM techniques to fabricate air-worthy parts
  - Constrained in high-risk, low-margin for error
  - Certification classically based on statistical analysis, process controls, inspections
  - ~10-year head-start
- Medical devices
  - Novel shapes, materials, surface finishes
  - Constrained in materials, life-cycle
  - Incredibly complex certification process
  - ~15 year head-start

Summary

- AM presents unique opportunities in the munitions design and fabrication space
- Many groups are working to implement AM in munition items
  - Some have created working parts and sub-systems
  - Complete munition items …
- New processing technologies are always accompanied by new defects and failure modes
  - Not a show-stopper, just diligent effort and planning
- Other industries may provide good examples of qualification / certification processes applicable to munitions

A LITTLE ROCKET SCIENCE

- Solid rocket propellant grains usually have a hollow “bore”
- Engineering the shape of the bore, controls the thrust profile

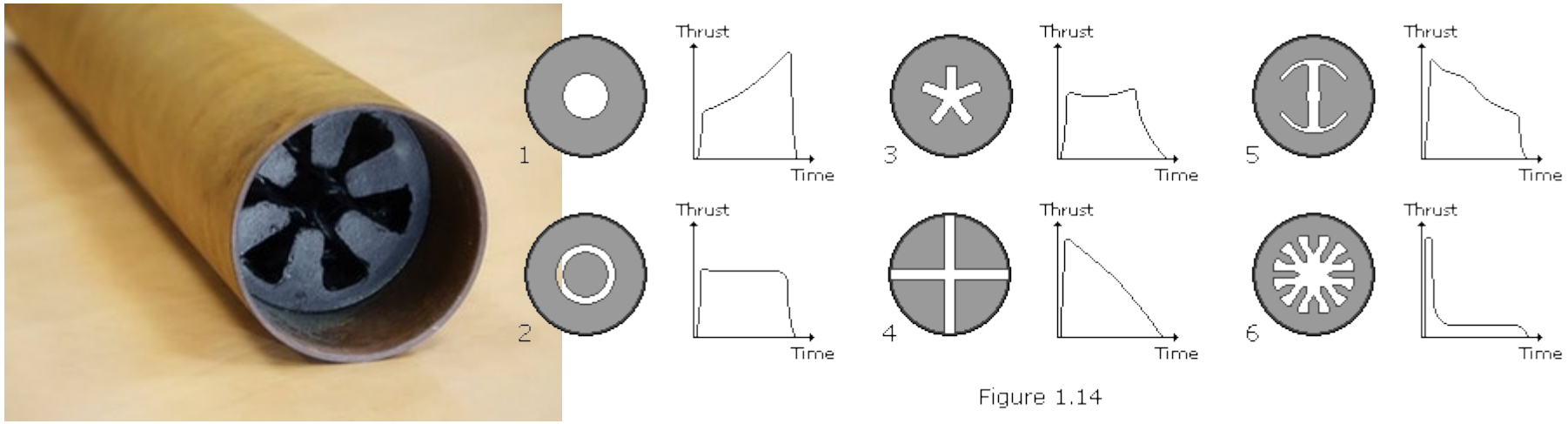
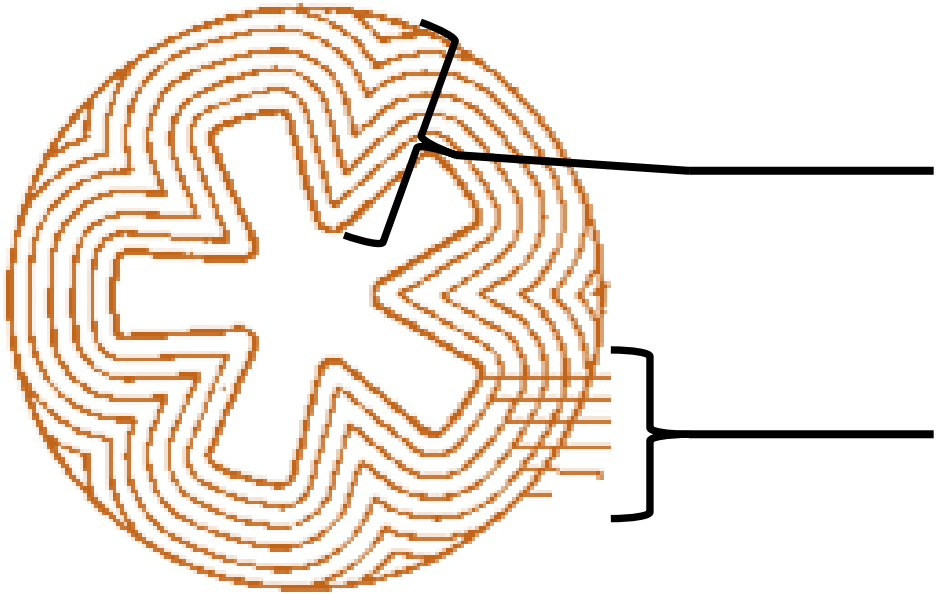


Figure 1.14

WHAT MAKES AM APPEALING?

- Fabricate multiple materials at once
- Create materials that are difficult / impossible with traditional bulk mixing
- Alter composition of a material with respect to geometry



Change critical parameters such as burn rate, elasticity, or fracture toughness across grain dimensions.

Enable thrust profile to change not because of geometry, but because the propellant composition is changing as the burn front moves outward.