NAVSEA WARFARE CENTERS
Indian Head

EMAM DLP Efforts for Printed Energetic Capabilities

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EMAM DLP Efforts for Printed Energetic Capabilities

Topic Area: Technology Development/Implementation

- Digital Light Processing (DLP) is one viable method for Energetic Materials Additive Manufacturing (EMAM).
- As in many production areas, DLP is opening the door to a wave of growth for CAD/PAD applications of 3-D printed energetics.

AM Background for Printed Energetic Capabilities

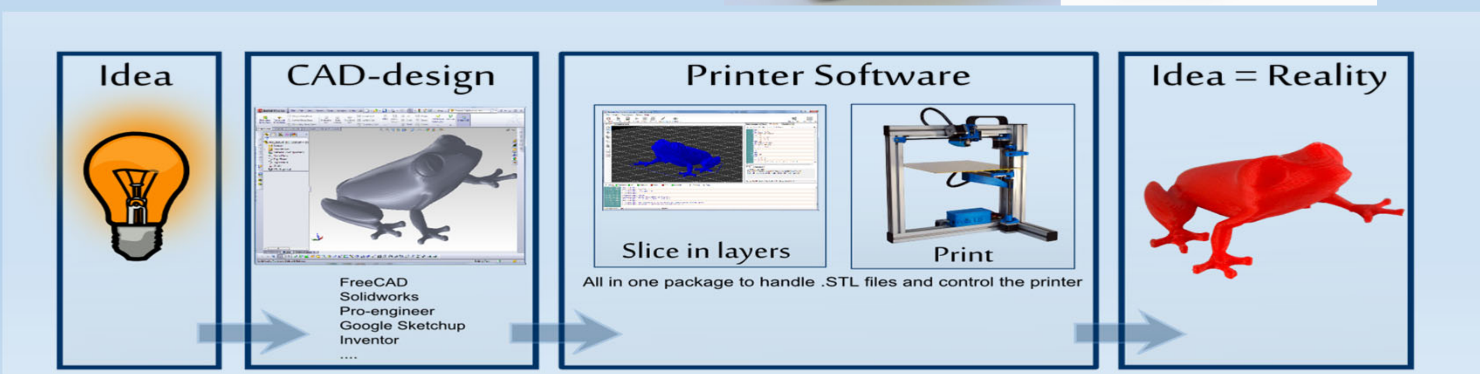
- Additive manufacturing (AM) or “3-D printing” technology
  - At the forefront of development for many modern industrial applications.
  - AM is currently underdeveloped for use with energetic materials.
- AM is currently underdeveloped for energetic materials use
  - Technologies for both development and maturing manufacturing need the focused of repeatable processes to sustain the supply of propellant for the fleet.
  - AM is inherently capable of propellant grain production with high consistency, repeatable through a precisely-controlled process required for ballistic performance results.
- NSWC Indian Head Division, EMAM
  - A rising leader in development and advancement of AM techniques
  - Useful in solid propellant grain production

EMAM DLP Objectives

- Promote innovation and advance manufacturing of Navy/Air Force solid propellant grains for Cartridge Actuated Devices (CAD) and propulsion systems
- Prove AM solid propellant grain feasibility
  - Develop a propellant feedstock compatible for AM
  - Explore AM printer suitable for energetic materials
  - Improve material quality to meet specification requirements
  - Create a manufacturing protocol, and scale-up procedures
  - Establish benchmark characterization tests for AM propellants
- Sponsor(s):
  - Navy ManTech, Manufacturing Technology Program Office
  - NAVSEA 05T
  - Joint Program Office

What is Additive Manufacturing ?

- Manufacturing technique of precisely depositing material, usually via computer numerical control, adding layer-upon-layer, until a 3-D object is formed
- Originally intended for rapid prototyping, but the last decade has expanded to other industries for alternative purposes:
    - Artisan / Hobbyist / Research
    - Low volume production
    - Customized item production
    - Esoteric part replacement
    - Production for complex geometries



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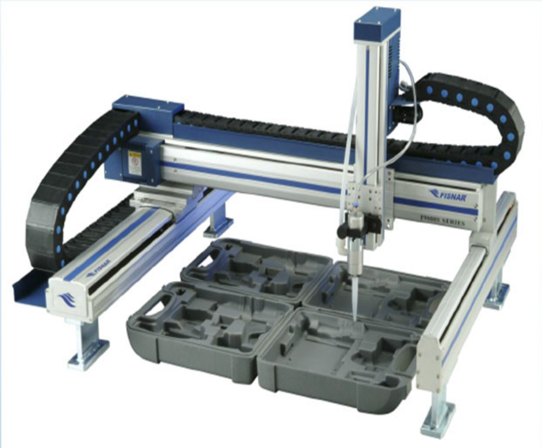
EMAM Machines We Use

Direct Ink Write (**DIW**), or Paste Deposition
- X,Y,Z Build volume: 600 X 600 X 200 mm
- Finest resolution – 100 microns
- Dispenses paste using pneumatics + single screw auger
- Operates like Fused Filament Fabrication (FFF) machine, (like a hot melt glue gun)



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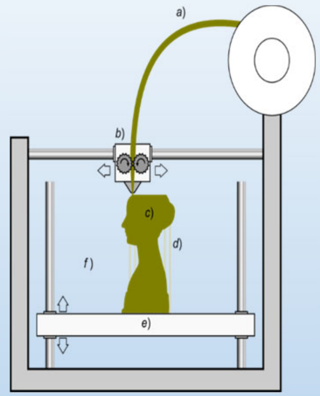

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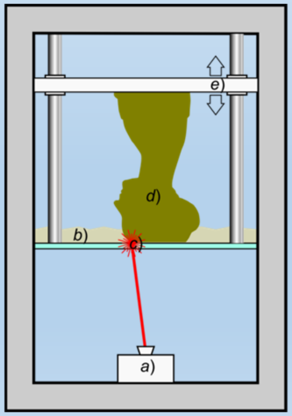
<u>Digital Light Processing</u> (**DLP**)
- X,Y,Z Build volume: 200 X 100 X 75 mm
- Finest resolution: 30 - 50 microns
- “Pro-consumer” COTS 3D printer
- Modified projector simultaneously cures a full x-section layer of UV sensitive resin.

Photo credit: B9Creations



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CAD Propellant Prototype

Hercules Experimental Smokeless (HES) 5808

- HES 5808 is an Ammonium Perchlorate (AP) based composite propellant, used in a variety CAD applications, as in aircrew escape systems
- HES 5808 propellant as an AM feedstock due to
  - Simple formulation, relatively insensitive to ESD, friction, impact.
  - Adjustable for AM use with no deviation of specifications
- Traditional manufacture of HES 5808 is an arduous process whereby dissolved propellant ingredients are squeezed through an extrusion die, before requiring excess solvent removal, to achieve gun-type propellant grains.

Photo credit: NSWC IHD, Dept E

DLP Material Approach

- Ultraviolet light (UV) curable feedstock under investigation for viability as materials to fill the criteria of product needs.

Sample preparation trials for mechanical properties

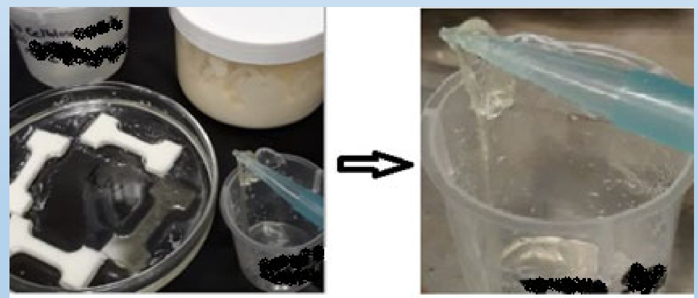
- Led to acrylate materials selection criteria.

TMA Samples: Cut, molded, or 3D Printed

Photo credit: NSWC IHD, Dept R

Cellulose based HES 5808 formulation modification.

- Ingredients to allow uv gelation.



Cellulosic w/ UV curative dogbone preparation

Plasticized Cellulosic gel w/ UV curative

Photo credit: NSWC IHD, Dept R

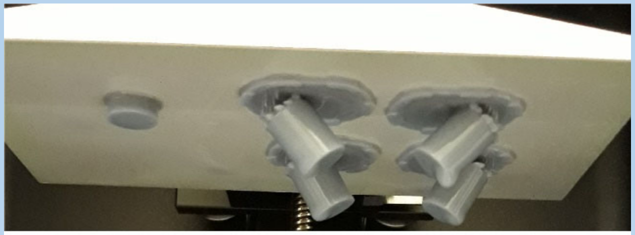
EMAM DLP Efforts for Printed Energetic Capabilities

- Acrylic based resins have stood out as one material class that lends itself well to DLP methodology.
    - Firm material properties with consistent dimensions and readily available

Instrumental Techniques

- As resolution is ~50 microns, contours appear smooth to the eye.
- Supports, orientation, and growth affect perforation opening.
- Overfilling of voids solved by printing at angles. Some objects could be geometrically challenging.

Post process by needle insert or support removal.



Use of supports and drainage angles.

Photo credits: NSWC IHD, Dept R

EMAM DLP Efforts for Printed Energetic Capabilities

- Printed Supports hold Resins in place.

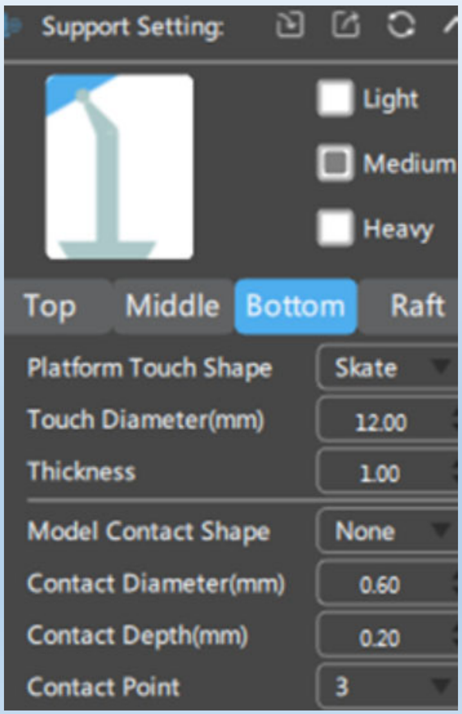


Photo credit: NSWC IHD, Dept R

- Slicer software provides options
- Rafts hold object from plate
- Support placement is key
- Allows growth on slanted surface
- Vary based on material strength
- Effect post processing

Photo credit: NSWC IHD, Dept R

EMAM DLP Efforts for Printed Energetic Capabilities

- Ultraviolet light (UV) curable
  - Requires formulation changes {initiator, additives, acrylic vs. cellulosic}
  - Finished prints are easily cleaned with common solvents.
  - End cleaning steps will fully harden print, though print is well cured.

Shore D testing	measurement conditions	Average of 5
Initial a	on Plate, 2 hours after print	81.6
Treatment c	Remove from plate, rinse w/ i-PrOH, EtOH	81.1
Treatment b	Light box or Sunlight treatment (2 hr)	80.4

Data credit: NSWC IHD, Dept R

Inspiration of AM Energetic Materials

Thinking outside traditional energetics manufacture

- Not bound by traditional manufacturing practices
  - Ability to pursue complex structures once not producible
- Novel materials introduction
  - Explore more efficient energetic materials,
  - change performance of energetics; use as desired (gradients, blends, etc.)
- Lenient workflow over traditional manufacturing
  - Quick turnaround on QC issues
  - Safe remote production
  - Economically sound low volume production
- Work well to compliment traditional manufacturing
  - Fill gaps in production as needed
  - Use in tandem with traditional manufacturing
  - Use in production of only certain parts

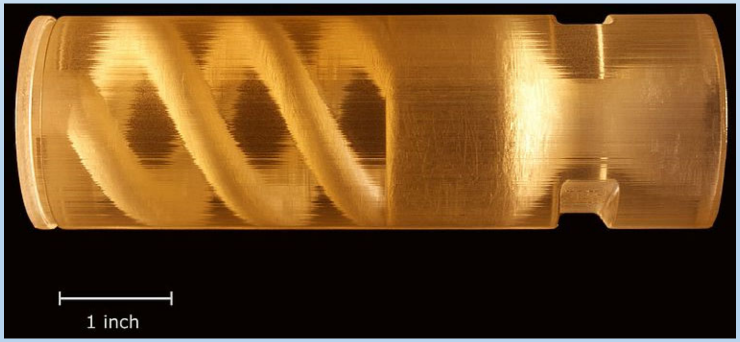


Photo credit: NSWC IHD, Dept E

Pros and Cons of AM Energetics

PROS

- Novel structures and materials – not bound by traditional manufacturing rules.
- Virtual tooling – dedicated toolsets not necessary to produce parts, just compatible printers.
- Designs can be changed virtually and with little downtime.
- Configuration Management - Archive/maintain CAD printing files.
- Great for low volume production of specialty items.

CONS

- AM of energetic materials is not fully mature.
- AM parts do not always behave like their traditional counterparts.
- No machine standardization for AM of energetic materials.
- Process for fleet implementation is not yet established.
- Not a direct replacement for manufacturing in large volumes.

Table credit: NSWC IHD, Dept E

EMAM DLP Efforts for Printed Energetic Capabilities

Summary:

- Digital Light Processing (DLP) is presented as a means to EMAM.
- DLP uses UV light to cure polymeric feedstock, for materials investigation to fulfill CAD/PAD product criteria.
- Well known engineering polymers/plastics (i.e., Acrylics, & Cellulosics) enable DLP 3DP methods.
- Gumstocks for a CAD/PAD UV printing application demonstrate a variety of chemical and mechanical possibilities.

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EMAM DLP Printed Energetics

Questions?