Direct Digital Manufacturing: Challenges and Potential

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Overview

- Defining "Direct Digital Manufacturing" or DDM
- The growing industry in Ohio you may not have noticed
- Broad overview of DDM technologies
- Applications of DDM
- Potential and Research Challenges
  - Materials development
  - Process modeling
  - Product design
  - Education

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What is "Direct Digital Manufacturing"?

- *Any of a variety of manufacturing technologies that enable 3D physical parts to be created directly from CAD or other data files using computer-controlled additive or subtractive techniques*

- Other names
  - Solid freeform fabrication
  - 3D printing
  - Rapid prototyping

A little history…

- First DDM techniques emerged in the mid 1980s
  - First version of Windows in 1985, MacOS 1984
- Largely a novelty for many years
  - Artistic endeavors
  - Prototypes
  - Architectural models
- Emerging as a tool for manufacturing parts for real products

Leaders

Print me a Stradivarius

How a new manufacturing technology will change the world

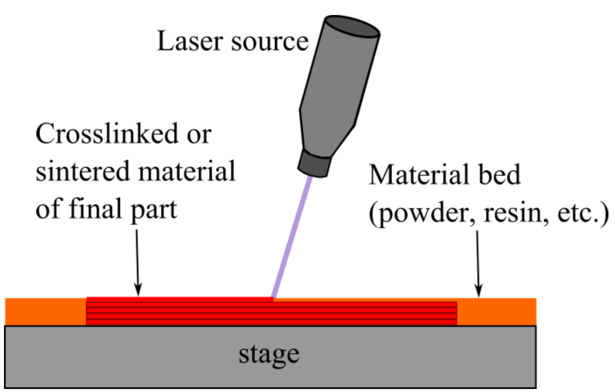
Direct Digital Manufacturing in Ohio

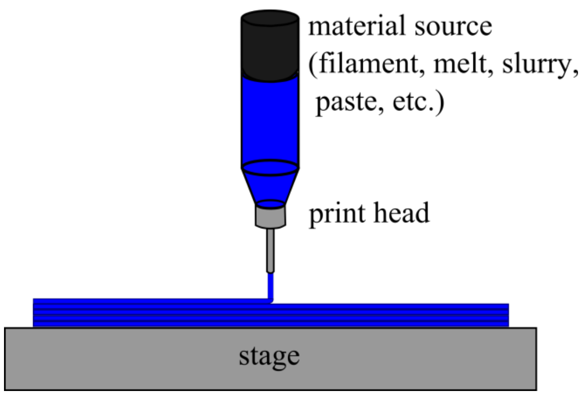
- This is a bigger industry than you might think….
- Some companies in Ohio doing this kind of work:
  - **3D Technical Services - Franklin**
  - Aerosport Modeling and Design – Canal Winchester
  - Astro Model - Eastlake
  - **Bastek – Vandalia**
  - Cam-Lem – Cleveland
  - DRS Industries - Holland
  - EWI - Columbus
  - Ferriot – Akron
  - Kovatch Casting – Uniontown
  - Laser Reproductions – Gahanna
  - Leyshon Miller Industries – Cambridge
  - MDF Tool Corp. – Cleveland
  - Morris Technologies – Cincinnati
  - **RapidScan - Vandalia**
  - **SelectTech - Miamisburg**
  - The Technology House – Solon
  - Thogus – Avon Lake
  - Toledo Molding & Die – Toledo
  - Toledo Prototype - Toledo

DDM Technologies

At least 25 different processes, mostly in two main groups

- **Laser initiated processes**
  - Start with a thin layer of material (usually powder or resin)
  - Laser fuses or crosslinks material in bed
  - Add another thin layer of material and repeat
  - Examples
    - Stereolithography
    - Selective laser sintering
- **Deposition processes**
  - Material deposited in successive thin layers from a "print head"
  - The "ink" may be:
    - Melted polymer
    - Dense suspension of particles (metal, ceramic, or polymer)
  - Examples
    - Fused deposition modeling
    - Robocasting
    - Multijet modeling





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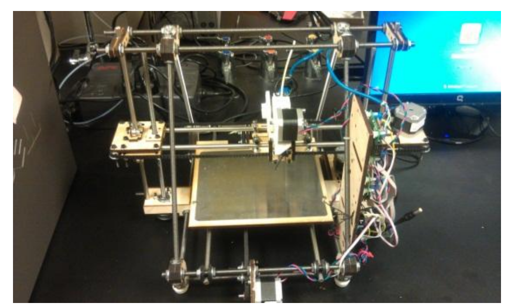
DDM Technologies

- Wide range of system costs
  - High end: $750,000
    - Large build areas (up to 18 ft^3)
    - Can be high resolution

  - Low end: <$1,000
    - Home-made kits
    - Low resolution



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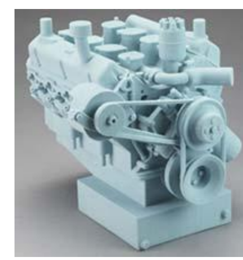
DDM Technologies

- Each technology good for a few applications
  - None optimized for more than about 6 different materials
- Several DDM technologies required for a complex system with many different kinds of parts
- All of them are relatively slow - if you need a million of a part
  - It would take a LONG time
  - It would cost far more than with more traditional technologies

What Is It Good For?

- No part specific tooling required
  - Largest cost with most traditional manufacturing technologies
- Energy efficient
- Low material waste

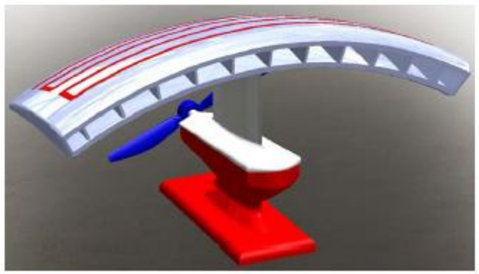
- Great for…
  - Custom, unique parts
  - Small production runs (100s to even 1000s)
  - Complex geometry



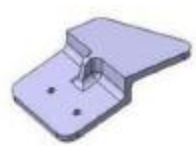
- Some common applications today
  - Developing tooling for traditional manufacturing
  - Prototyping
  - Jewelry design
  - Models
  - Custom fit medical devices
  - MANY unique and small production run plastic parts
  - Potential for the future…

What else COULD you do?

- Custom design of UAVs



- USAF has identified 1500 parts for the next generation joint strike fighter to be made using DDM


- Unfortunately, imagination is *NOT* the only limitation right now…

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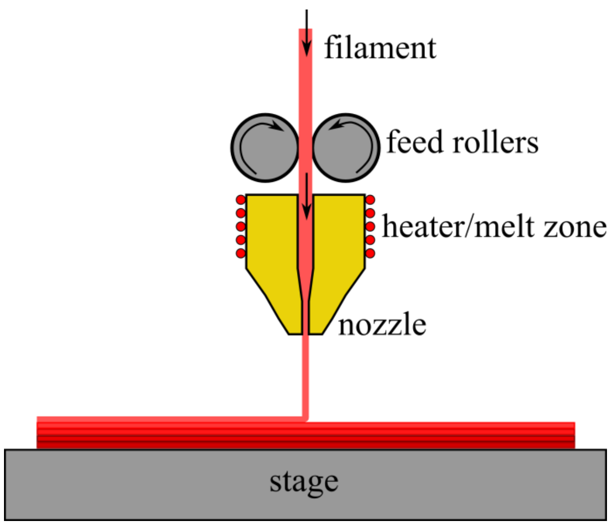
Challenges

- Few materials optimized for any process
  - Example: for commercial fused deposition modeling systems, you can use…
    - ABS
    - Polycarbonate
    - Ultem
    - Polyphenylsulfone
- No process design rules
  - Limited understanding of how adjusting system parameters will impact part properties
  - Either use factory settings, or trial-and-error
  - Some commercial systems have very limited ability to adjust
- No product design rules
  - Properties of final part often depend on how layers are put down
  - Opportunity for low density, honeycomb type structures
- No educational infrastructure
  - A few short courses
  - One book in print

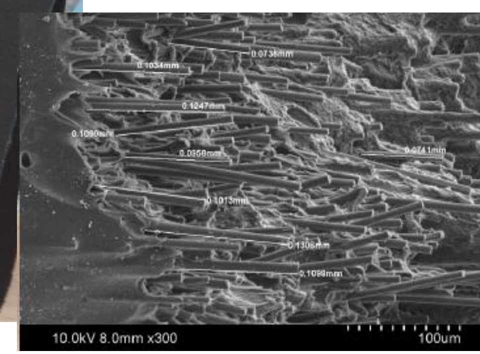
Challenges = Opportunities for Research that Makes an Impact!

Materials Development for DDM

- Composites
  - Demonstrated with some success in the lab
  - Even less understanding of process/property relationships
  - Example below for Fused deposition modeling
    - Nylon with chopped carbon microfiber used to make airfoil



- Nanotechnology and functional or “Smart” materials
  - Anti-microbial coating?
  - Enhanced mechanical strength?
  - Greater thermal conductivity?
  - Embedded devices?
  - ???



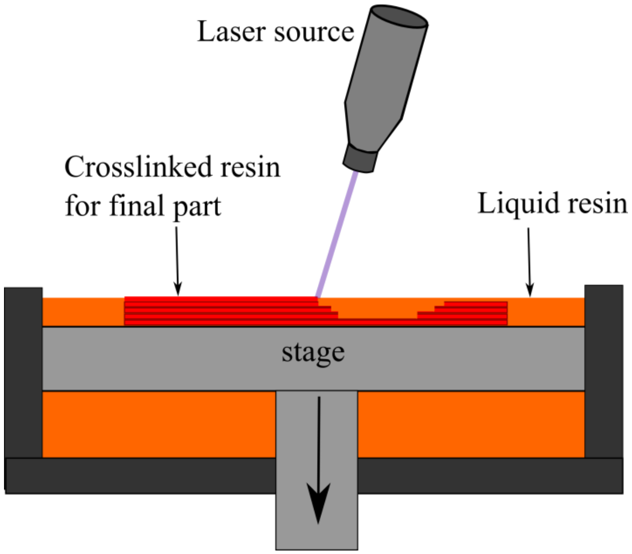
Process Design Rules

- Limited understanding of relationship between
  - Process parameters
  - Materials properties
  - Part properties

Without this knowledge, materials development is VERY difficult!!!

- Consider stereolithography process parameters:
  - Laser wavelength
  - Laser intensity
  - Exposure time of resin to laser
  - Optical properties of resin
  - Resin chemistry
  - Resin additives/fillers
  - Resin temperature
  - Resin thermal properties
  - Environment temperature
  - Resin layer thickness
  - Post process curing
  - Others?

How do these impact the properties of the final part/material?



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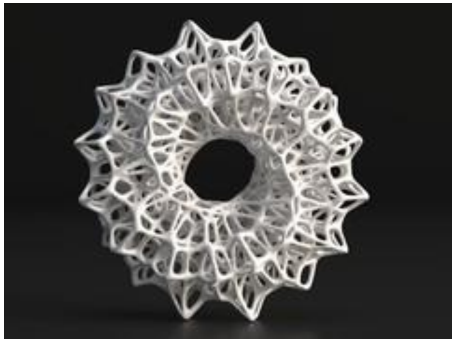
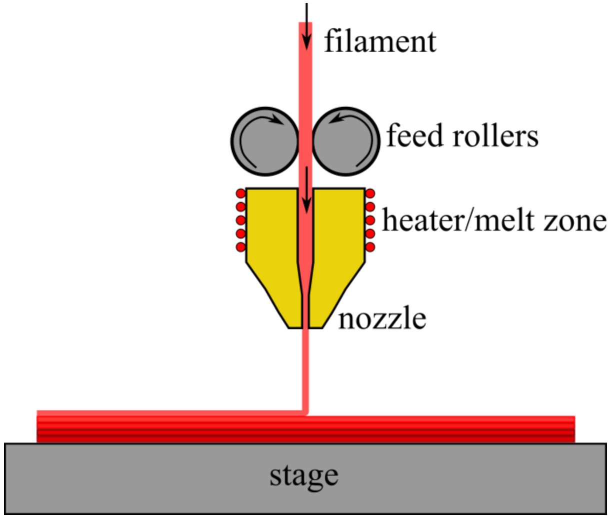
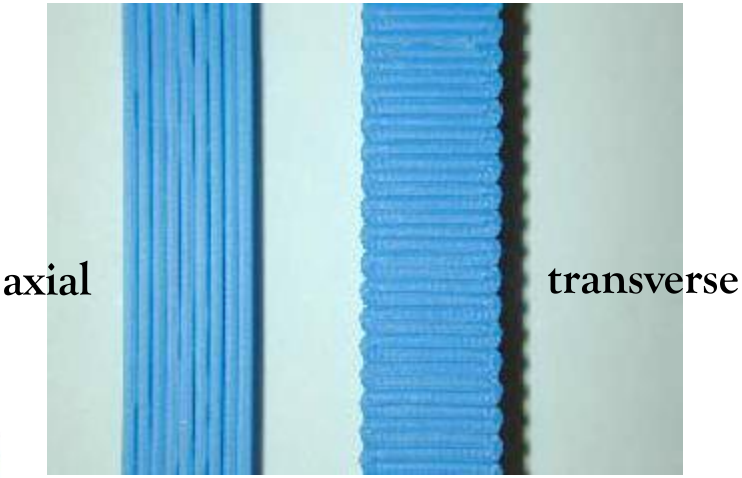
Product Design Rules

- DDM enables novel designs
  - Complex geometries
  - Lightweight, honeycomb structures



- How the part is "sliced" impacts its properties





DDM Education

- Growth of DDM requires engineers, technicians, and scientists with training in the field
- Let's make a quick comparison between DDM and injection molding

Injection Molding

- Books listed on Amazon.com: >1000
- College courses in Ohio: >10

DDM

- Books listed on Amazon.com: 1
- College courses in Ohio: used in 2-3, not a major topic in any

Conclusions

- The era of direct digital manufacturing is arriving!
  - Rapidly growing industry
  - Potential for huge growth – many manufacturing jobs!!
- Challenges = Research Opportunities
  - Materials development
  - Process and product design rules
  - Education

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