IME 601 - FUNDAMENTALS OF MFG. ENG.
POWDER PROCESSES / ADDITIVE MFG — BASIC CLASS NOTES

Reading Review and Class Preparation
This should be filled out prior to class.

Key Concepts to Be Discussed in Class:

Questions About Subject Matter for Class Session:

Outline

- Defintion of Powder Processing
  - Role of Surface Energy
- Powder Processed Materials
  - Products Made From Powder Processes
- Powder Processing Steps
- Advantages and Disadvantages of Powder Processing
- Additive Manufacturing
  - 3D Printing

Powder Processing

- A Technique Whereby Powder Particles are Joined to Form a Continuous Solid Part Without Melting
  - Solid State Process
  - A Single Part is Formed From Powder

Casting	Powder Processing
Liquid is Poured into a Defined Shape and Solidified	Powder is Poured into a Defined Shape and the Powder Particles are Joined

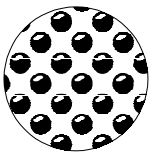
Powder Processed Materials

- Avoid Melting
  - High Melting Temperature Materials
  - Strong Oxide Formers
- Intricate Parts
  - Reduce Need for Machining
  - More Sophisticated Parts than Casting
- Ceramic - Metal Mixtures

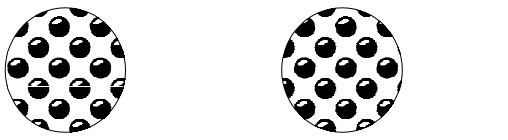
Material	Tm (C)
Aluminum	660
Copper	1083
Iron	1536
Tungsten	3410
Tantalum	3000
Molybdenum	2610
Nickel	1453
Alumina	2050
Silica	1400
SiC	2200
Si_3N_4	1900

Surface Energy

- Atoms on Surface of Particle
  - Have Higher Energy
  - Are More Reactive
  - Are UnderBonded
- Surface Energy (γ)
  - Energy Per Unit Area
  - Not Energy of the Surface



Higher Total Energy

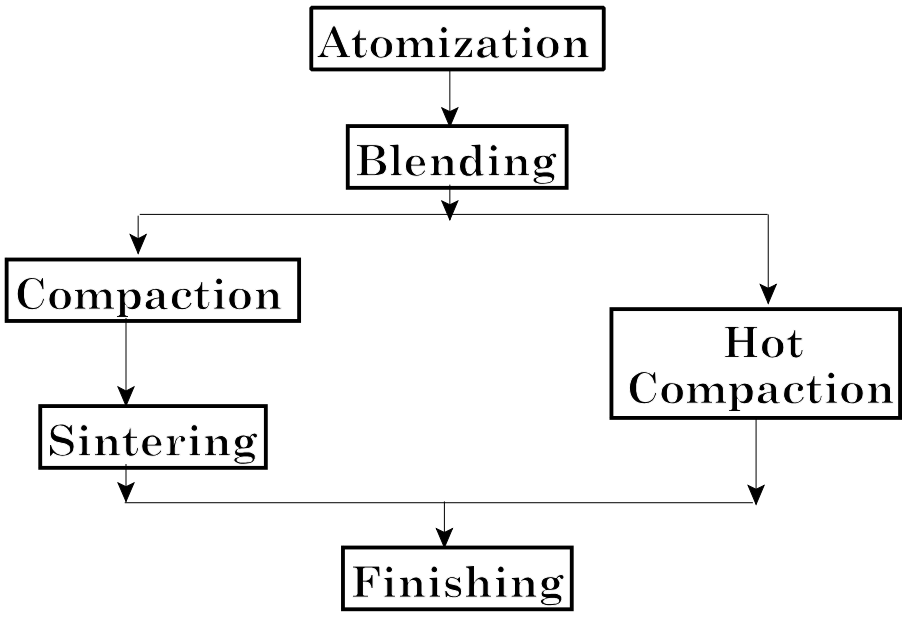


Lower Total Energy

Concept Question

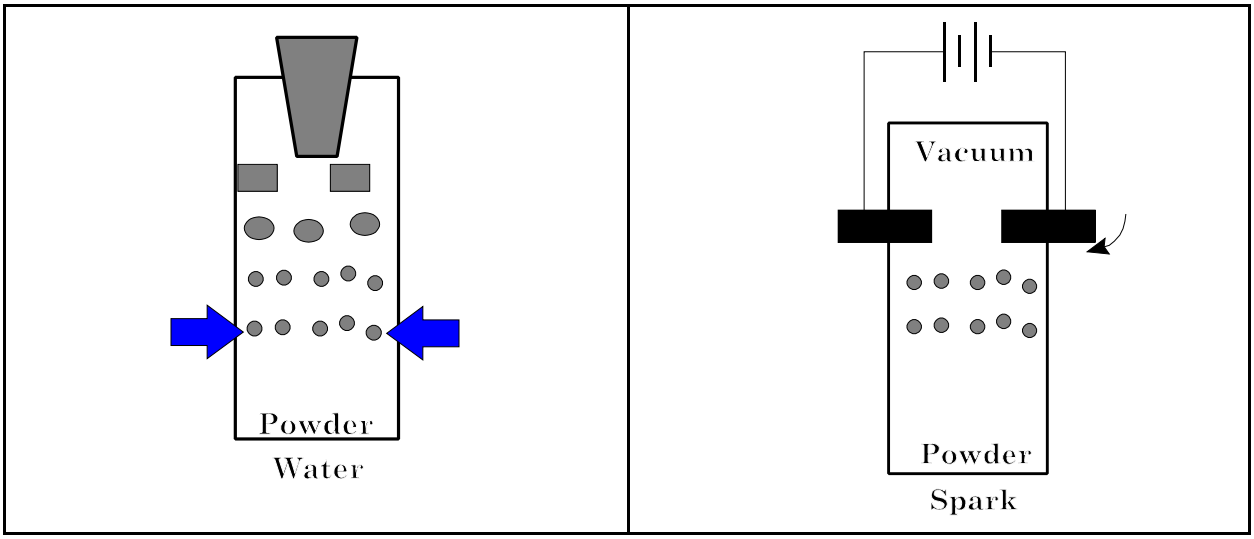
- What Has to Be Done to Make a Part Using Powder Processing?
  - Start With Chunk of Material
  - Finish With Part
  - Think of All Steps (Conceptually)

General Process



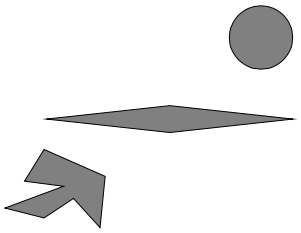
Making Powder

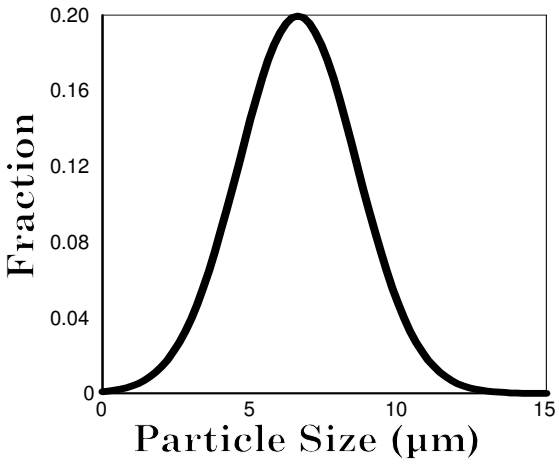
- Atomization
  - Water or Gas

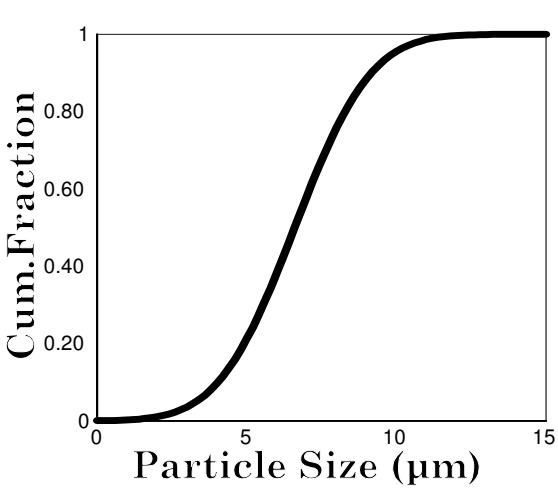


Powder

- Powder Can Have Many Forms
  - Ideally Spherical
  - Needle Like
  - Flake Like
- Powder Size Distribution







Blending

- The Powder Must Be Mixed
  - Different Particle Sizes
  - Different Materials

- Add Lubricant / Flux
  - Removes Air
  - Can Prevent Oxide Formation on Metals

- Add Binder
  - Need to Be Able to Shape Part

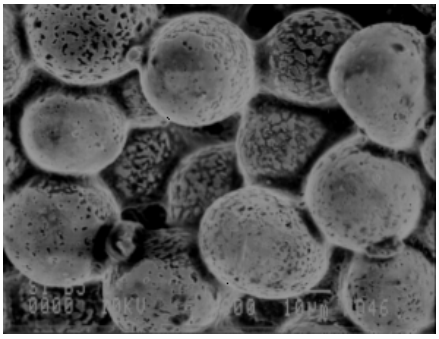
Compaction - Green State

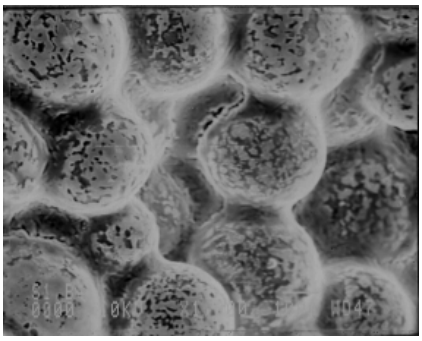
- The Powder Needs to Be Put in Die
  - Initial Shape Formation
- Compaction Method Depends on Complexity of Part
  - Rolling
  - Extrusion
  - Injection Molding
  - Isostatic Pressing

Material	Pressure (MPa)
Aluminum	70-275
Iron	350-800
Tungsten	70-140
Tantalum	70-140
Alumina	110-140

Sintering

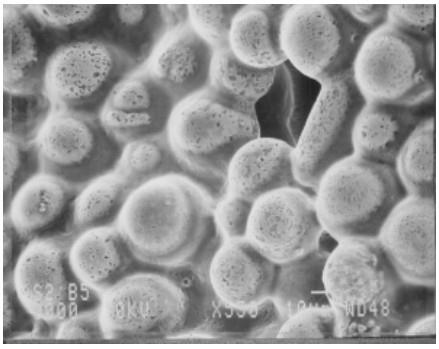
- Green Compact is Heated
  - 70-85% of Melting Point
  - Sometimes Under Pressure
- Particles Actually Join
  - Necking
  - Pore Elimination
  - Grain Growth

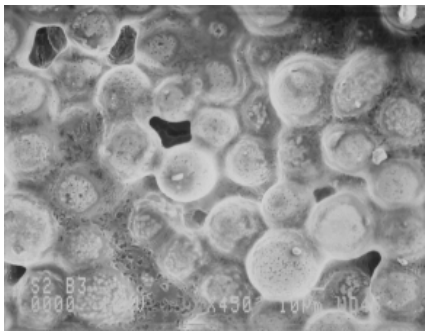




Sintering Continued

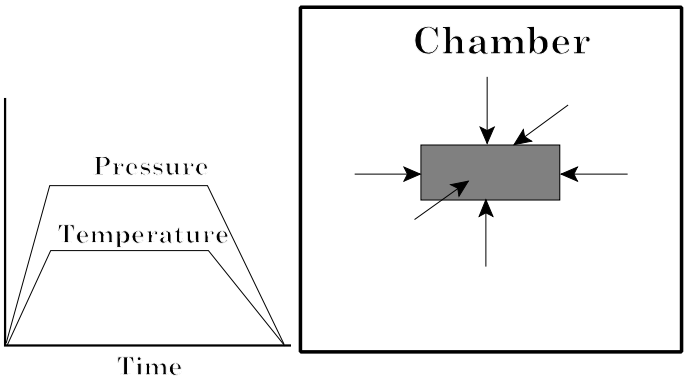
- The Pores Between Particles Are Eliminated
- Can Be Enhanced With Liquid
  - Can Remain in Alloy
  - Can React





Hot Isostatic Pressing

- Combines Two Steps
  - Compaction
  - Sintering



Sintering Temperatures

- Lower Than Melting Point

Material	T (C)	Tm (C)
Aluminum		660
Copper	760-900	1083
Iron	1000-1150	1536
Tungsten	2350	3410
Tantalum	2400	3000
Molybdenum	2050	2610
Nickel	1000-1150	1453

In-Class Exercise

- Compare Sintering to Casting

Similarities	Differences
Advantages	**Disadvantages**

Summary

- Means to Fabriacte Parts Without Melting
  - Requires Several Steps
  - Intricate Parts

Parts Made Through Powder Processing

- Turbine Blades
- Jet Engines
- Gears
- Valve Inserts
- Medical Implants
- Electronic Components
  - Diodes, Heat Sinks
- Tool Dies

3-D Printers

- Turbine Blade Made in Single Machine

Wikipedia

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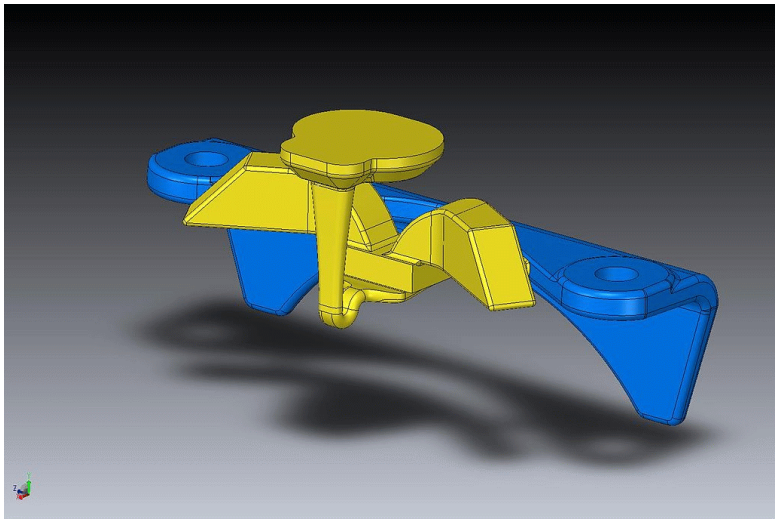
CAD File

- A Good CAD File
  - Is the First Step
- Sent to Machine



OKFoundry Company from Richmond, USA

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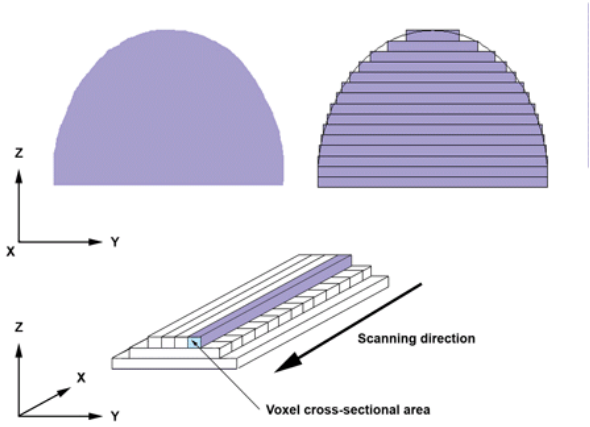
Layering

- Resin or Powder Blend



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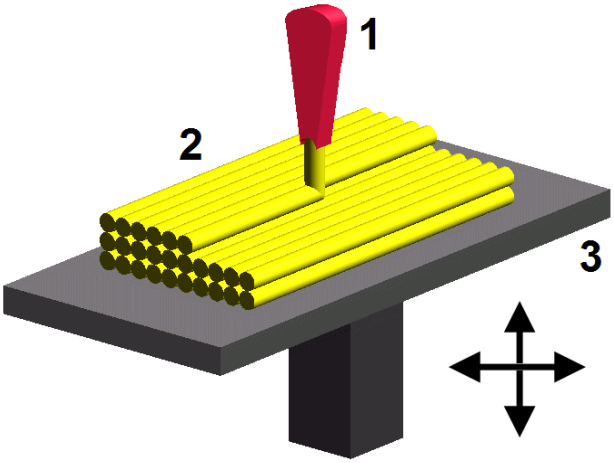

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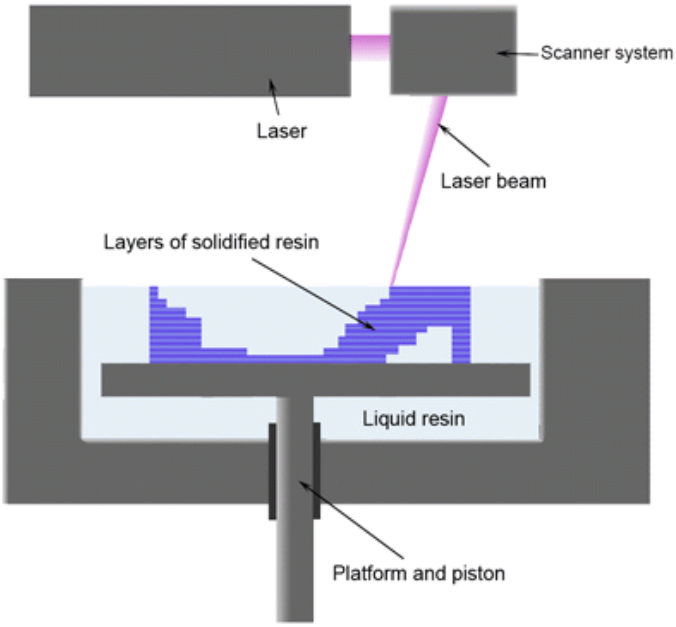
StereoLithography

- Similar to Sintering



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Summary

- A New Paradigm
- Old/Traditional
  - Make in Many Steps
  - Usually Bulk Forming/Casting Followed by Machining

Wikipedia

- New
  - One Machine Does Everything
  - Material Only Where We Want It

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