Wintec
WAIKATO INSTITUTE OF TECHNOLOGY
Te Kuratini o Waikato

Powder Metallurgy

Thermal processing in MIM and Metal 3d Printing

PRESENTED BY:

ELNIK SYSTEMS

CLAUS J.JOENS
President
Elnik Systems, LLC

PGE
INJECTION MOULDING LTD

Overview

- Company Overview
- Processing Technology Review
  - Metal Injection Molding (MIM)
  - Metal 3d Printing
- 1st Stage Debinding
- 2nd Stage Debinding
- Sintering
- Staging - Ceramics
- Quality Control
- Overview of DSH Technologies/Elnik Systems GmbH
- Questions

Elnik Systems, LLC

A Debind and Sinter Equipment Manufacturer/Provider for the Powder Metal Industry

<u>Headquarters</u>

Elnik Systems, LLC
MFG/Fabrication
Service
Spare Parts
Demo Equipment
-DSH Technologies, LLC

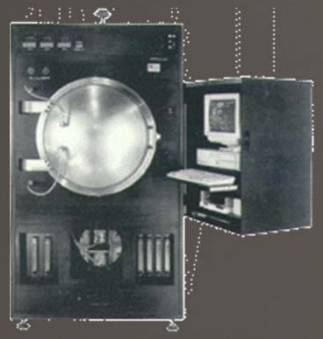
Elnik Systems, GmbH
Service
Spare Parts
Demo Equipment

Elnik's Core Beliefs

- **Innovation**
  - Innovation leads to improvement and enhancement. Elnik is constantly looking to make its equipment more efficient and effective
  - Elnik's sister company, DSH Technologies with its production sized furnaces, provides a portal to test and experiment with new concepts, components, and solutions for customers to ensure complete functionality.
  - 3-6 Months on in house testing prior to release
- **Quality**
  - Elnik will never sacrifice quality of its equipment and sub-components in order to lower price.
- **Experience**
  - Elnik strives to provide its customers with the most exceptional customer support, service and delivers products and solutions that are functional and effective.
- **Excellence**
  - Elnik continuously strives for excellence in its equipment operation and customer experience.
  - Working relationships with existing customers leads to better overall equipment functionality and customer support

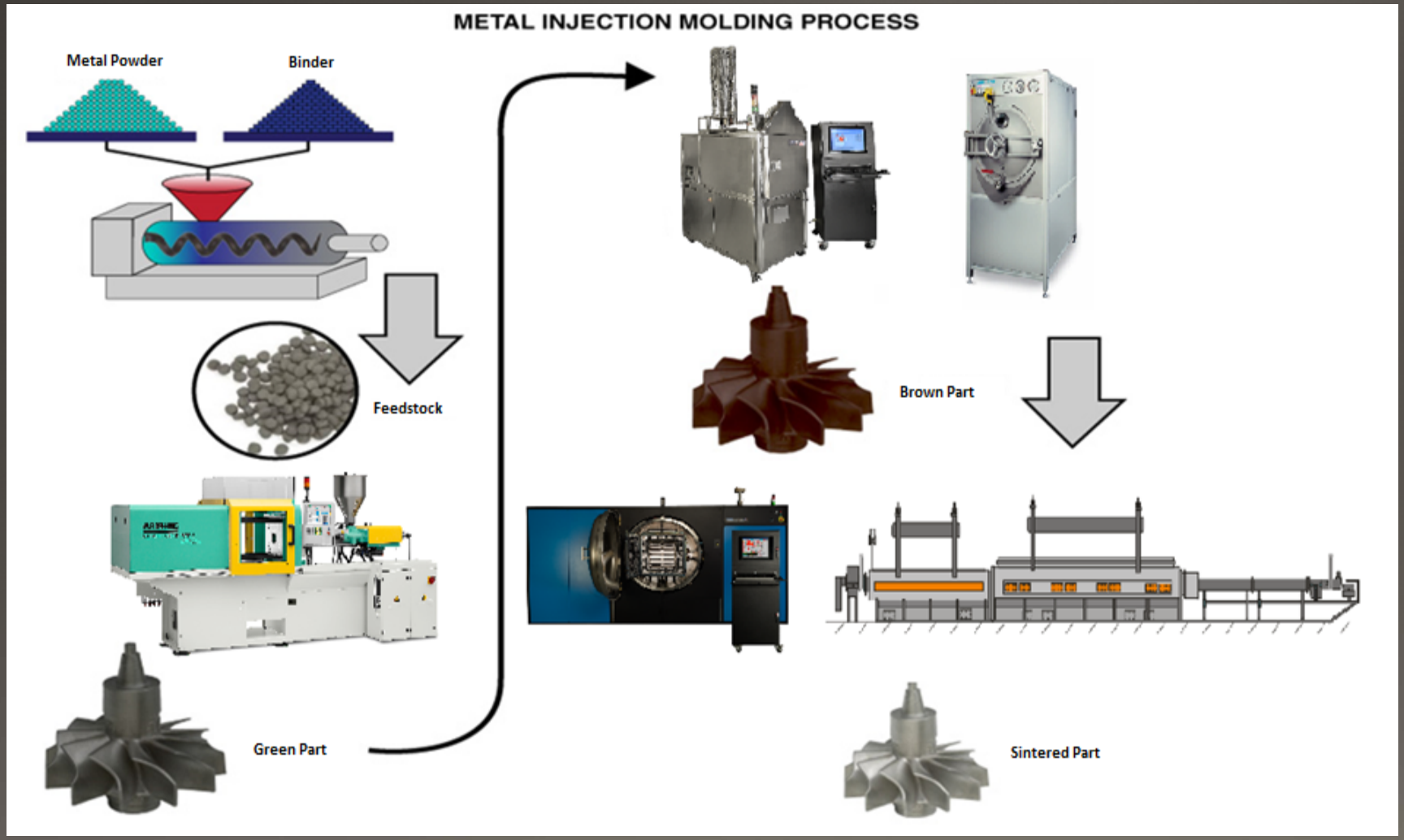
History by Pictures



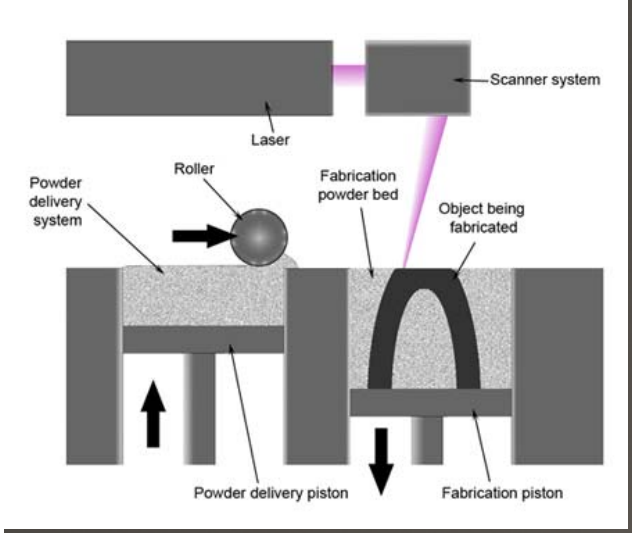


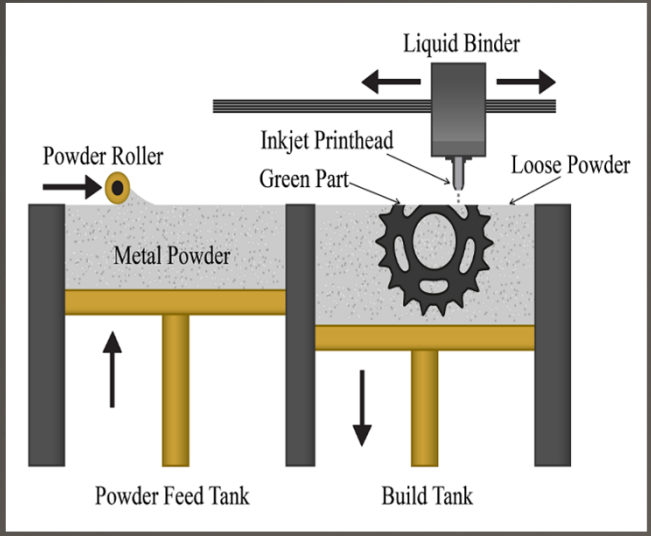


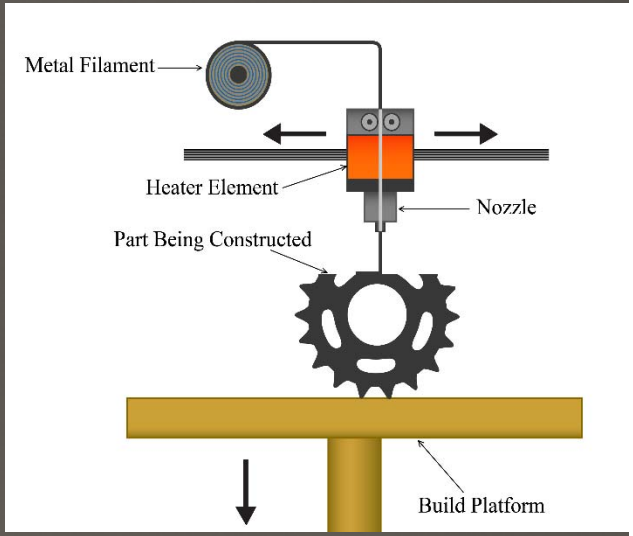

MIM Process Technology



Metal 3D Printing







Powder Bed Fusion

Metal to Metal Fusion
Via Laser

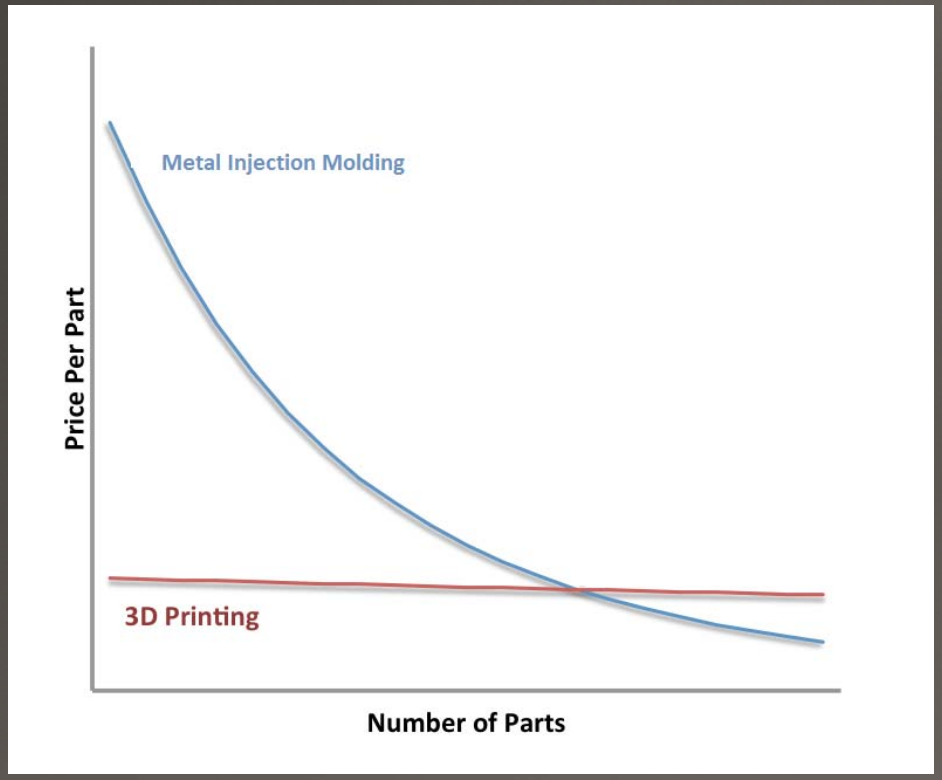
Powder Bed Adhesion

Metal to Metal adhesion
Via binder

Filament Deposition

Layer by Layer printing of Metal/Binder feedstock or filament

Technology Cost comparison



Metal 3d Printing works best in low volume high complexity

MIM works best in mid/high volume high complexity

1st Stage Debinding

- Key step in process – Careful Process Control

- Removal of Wax/Polymer
  - Thermoplastic (Parafin,Carnuba, Oils), Polyacetal(POM) , PEG

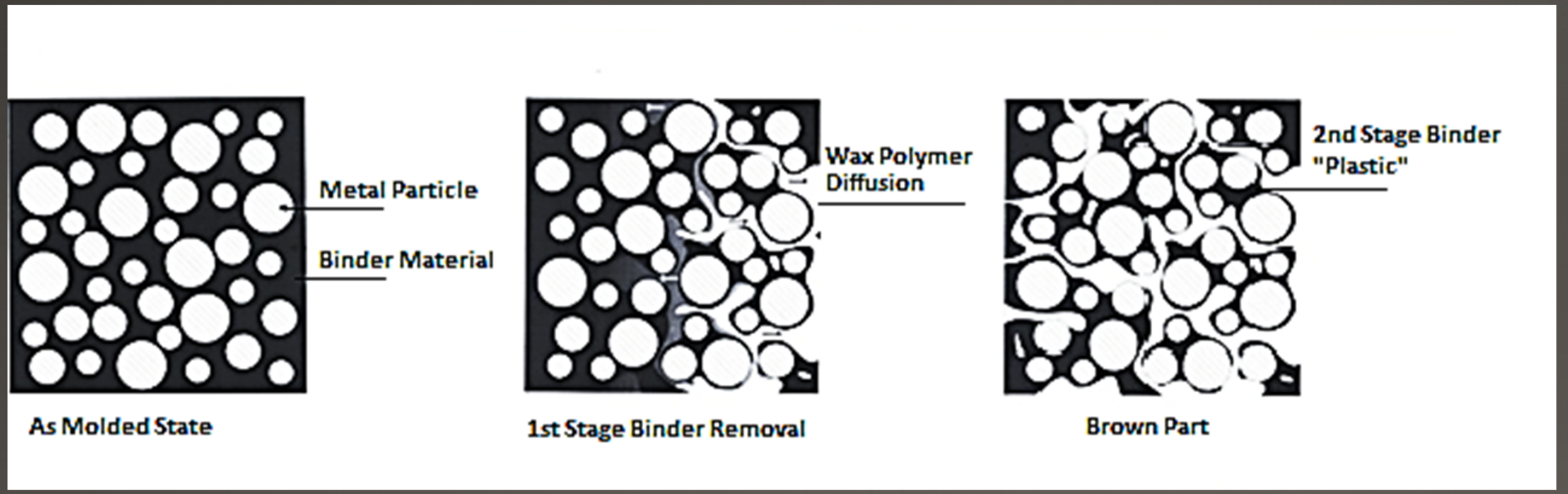
Examples of Debinding

- **Solvent**
  - Perchlorethylene, Trichlorethyene (Non-Flammable)
  - Heptane, Hexane, Acetone (Flammable)
  - Lower Temp, Slower Debind Time
- **Catalytic**
  - Nitric Acid / Oxalic Acid
  - Higher Temp, Faster Debind Time
- **Water**

Solvent Debinding

- Solvent
  - Perchlorethylene, Heptane, Hexane, Trichlorethylene, Acetone, Organics
    - Country Regulations
    - Disposal Requirements

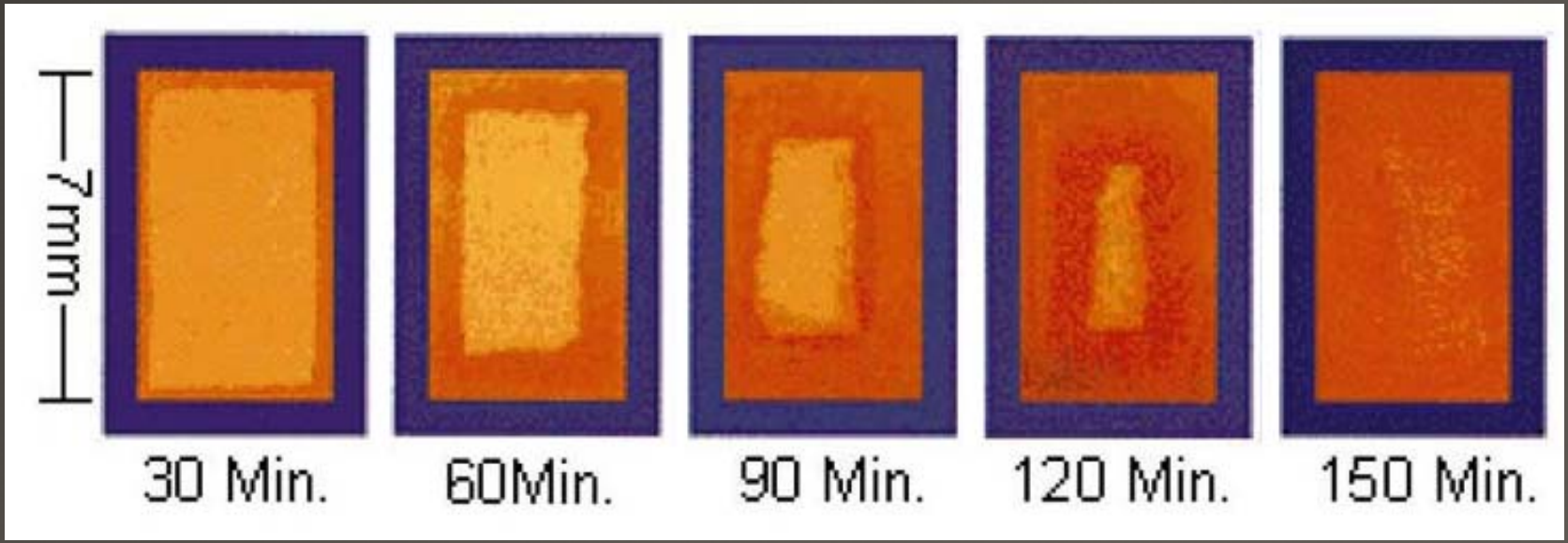
Solvent Debinding



Catalytic Debinding

- Catalytic
  - Nitric Acid
    - Safety Adherence
  - N2
- Polyacetal/POM Based Feedstocks

Catalytic Debinding

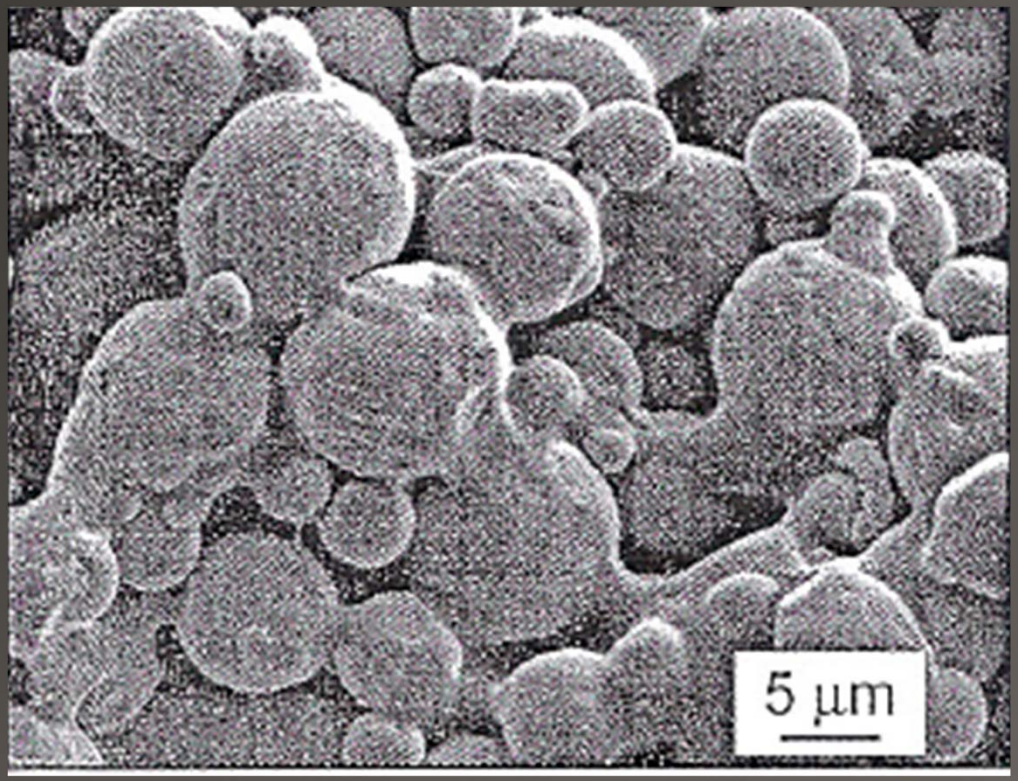


Water Debinding

- Water
  - Requires a drying oven
  - Disposal Requirements
  - Increased Process Time
  - Environmentally Friendly

Brown Part

2nd Stage Binder and Metal

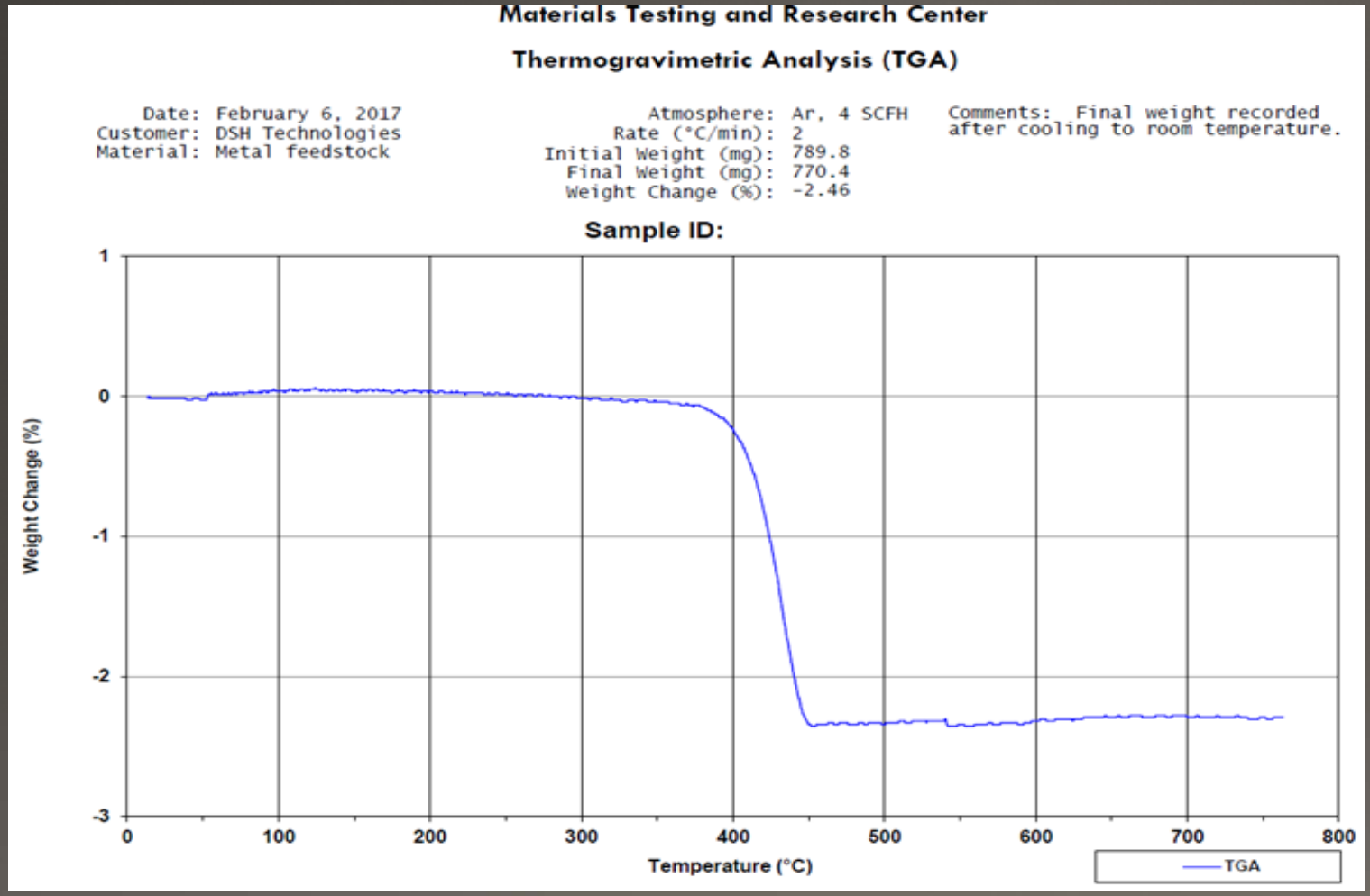


Scanning Electron Micrograph (SEM) of "Brown Part"

Binder located at Metal Particle contacts.

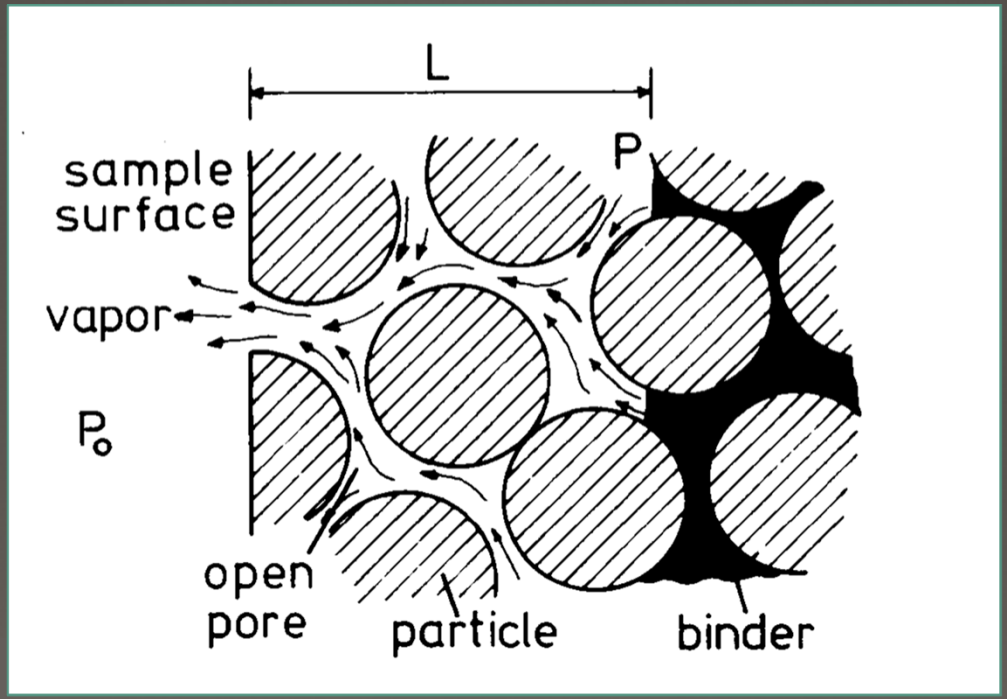
Holds particles in position

TGA - Thermogravimetric Analysis



2nd Stage Debinding

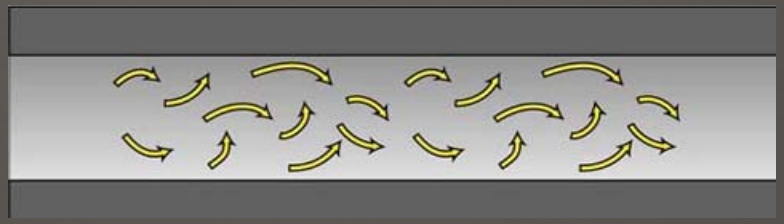
- Thermal Binder Removal – Diffusion through open pores where WAX was
- "L" Transport distance increases over time.
- Hold times are dependent on part Geometry and Wall Thickness



Gas Flow

TURBULENT at 1013 mbar

High PSI Flow creating uneven flow and shadow effect.

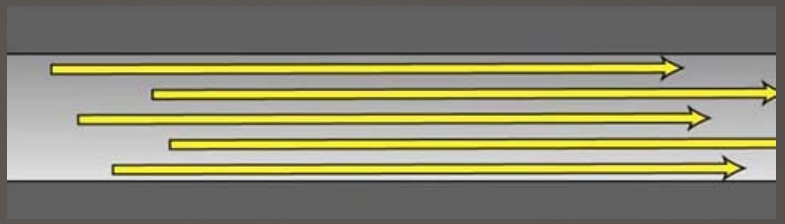


LAMINAR at 400 mbar

Smooth/Even Flow

No Shadow Effect

Efficient binder removal

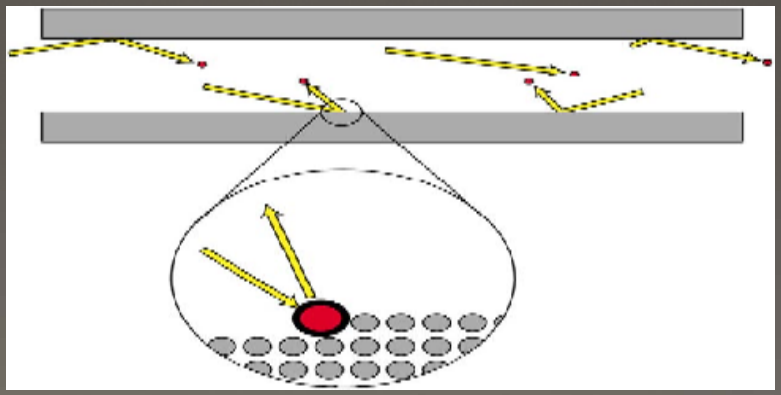


MOLECULAR at 0.133 mbar

Collisions/Unpredictability

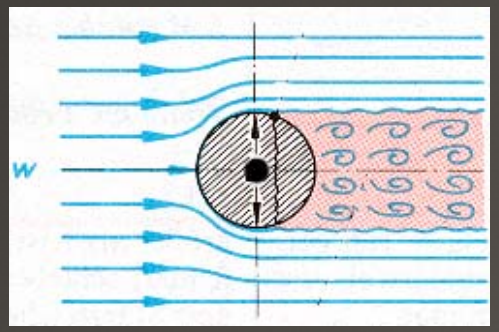
Random Flow

Contamination – gas escapes to cold walls

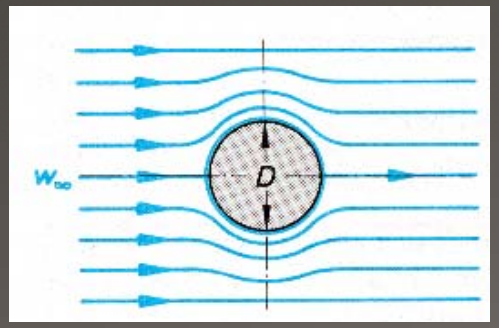


Laminar Gas Flow

Turbulent Flow



Laminar Flow



Reynolds number (Re) – Flow Pattern in different Flow Situations

Turbulent – High Reynolds (Inertial Forces)
Laminar – Low Reynolds (Viscous Forces)

Uneven gas distribution
= Uneven Temperature Uniformity
= Varying Debinding Results

Laminar Gas Flow
Even binder Removal
No re-deposition of binder on the part
Partial Pressure (400 mbar)

Gas Management

Key Design Features

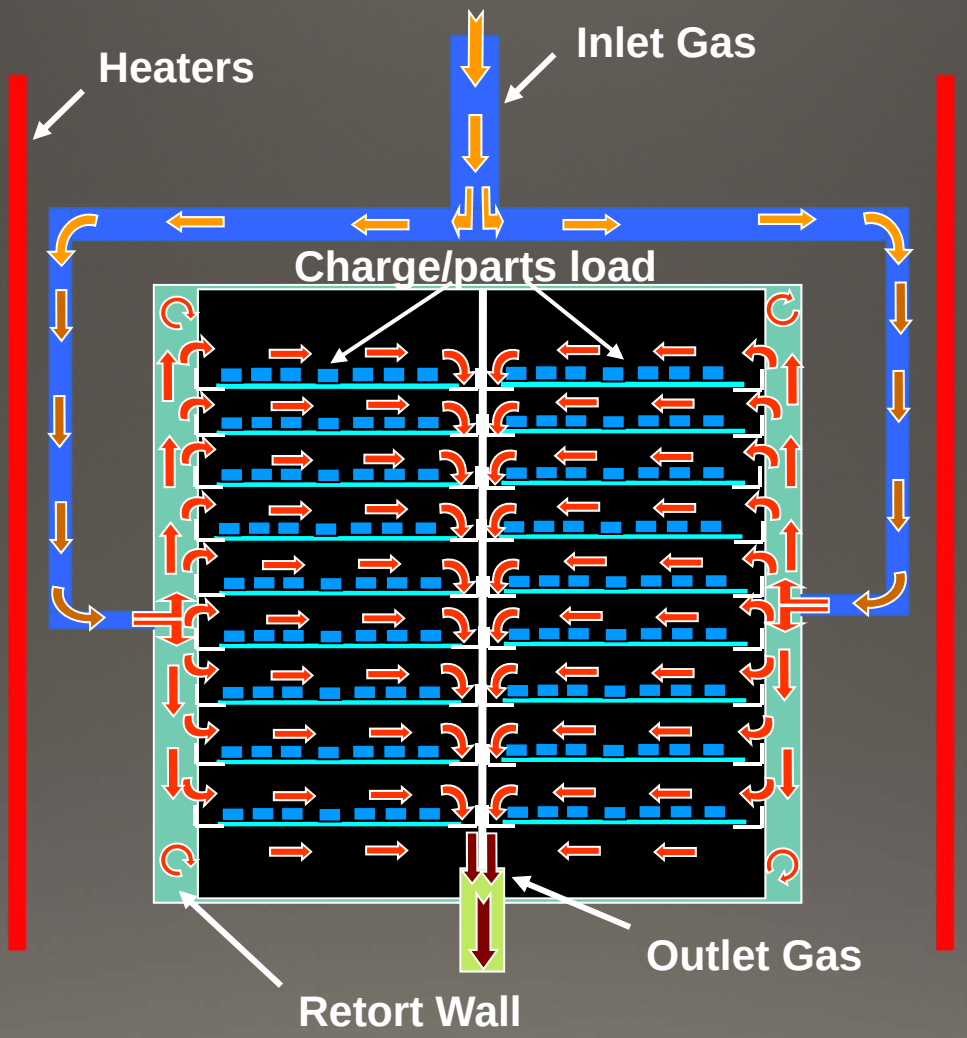
Heated Process Gas
Shortest Distance Binder Removal

Low Temperatures

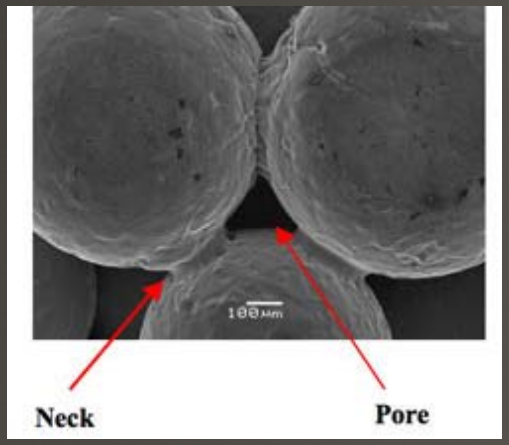
Conduction/Convection
Excellent Temperature Uniformity

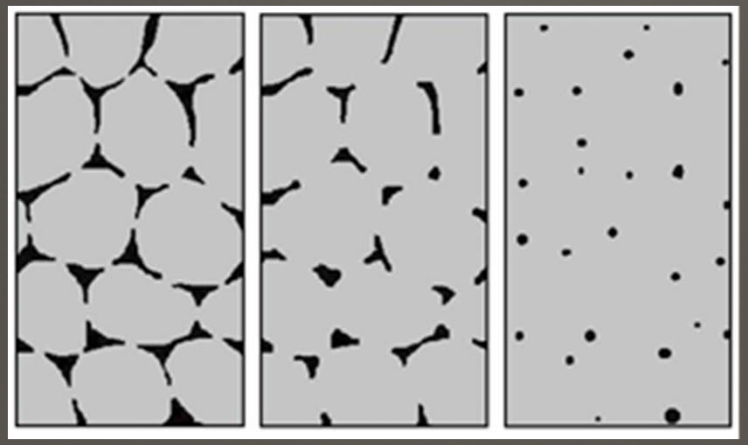
High Temperatures

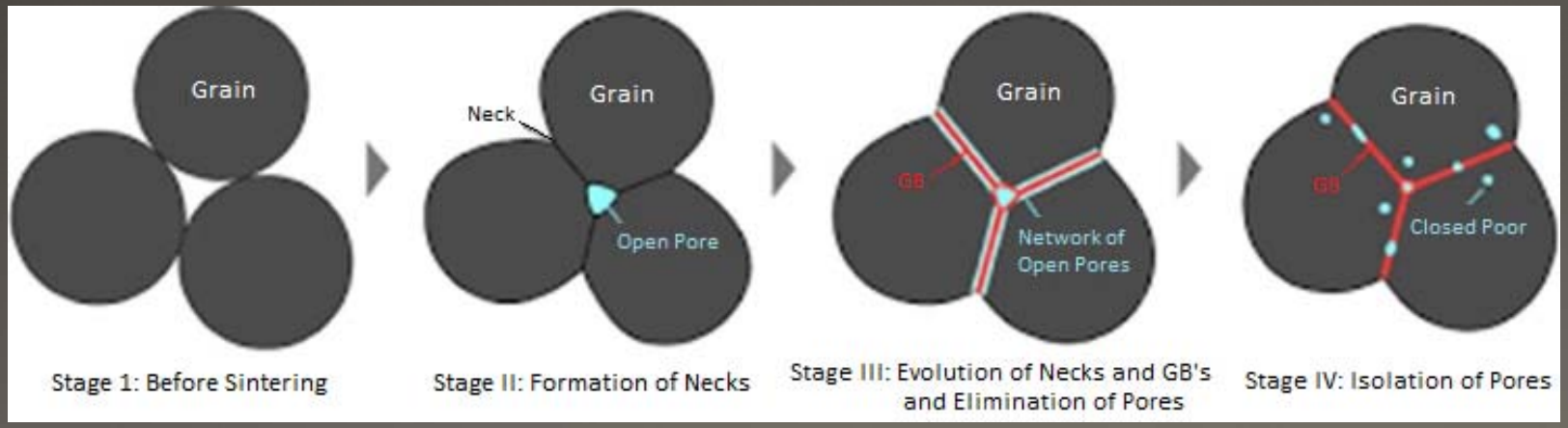
Radiation
Tight Temperature Distribution



Sintering


Neck
Pore




Grain
Grain
Neck
Open Pore
Grain
GB
Network of Open Pores
Grain
GB
Closed Poor
Stage 1: Before Sintering
Stage II: Formation of Necks
Stage III: Evolution of Necks and GB's and Elimination of Pores
Stage IV: Isolation of Pores

Sintering - Atmospheres

- **Hydrogen (H_2)** – reducing atmosphere
  - Avoiding Oxidation of metal particles
  - Carbon Control
- **Inert (Nitrogen -N_2)**
  - Steel or Ferrous material
  - Uses Carbon as Alloying Element
- **Argon (Ar)**
  - Titanium, Super Alloys
- **Vacuum**

Sintering - Expectations

- **Shrinkage**
  - 18-22% depending on feedstock MFG
- **Tolerances**
  - 0.3% typical
- **High Density**
  - Excellent Temperature Uniformity
  - Getting Close to Solidus Temperature
- **Carbon, Oxygen, Nitrogen Control**
  - High Purity Gases (99.999%)
  - Eliminating Leaks
- **Tensile Strength, Ductility, Grain Growth**

2nd Stage Debind and Sinter

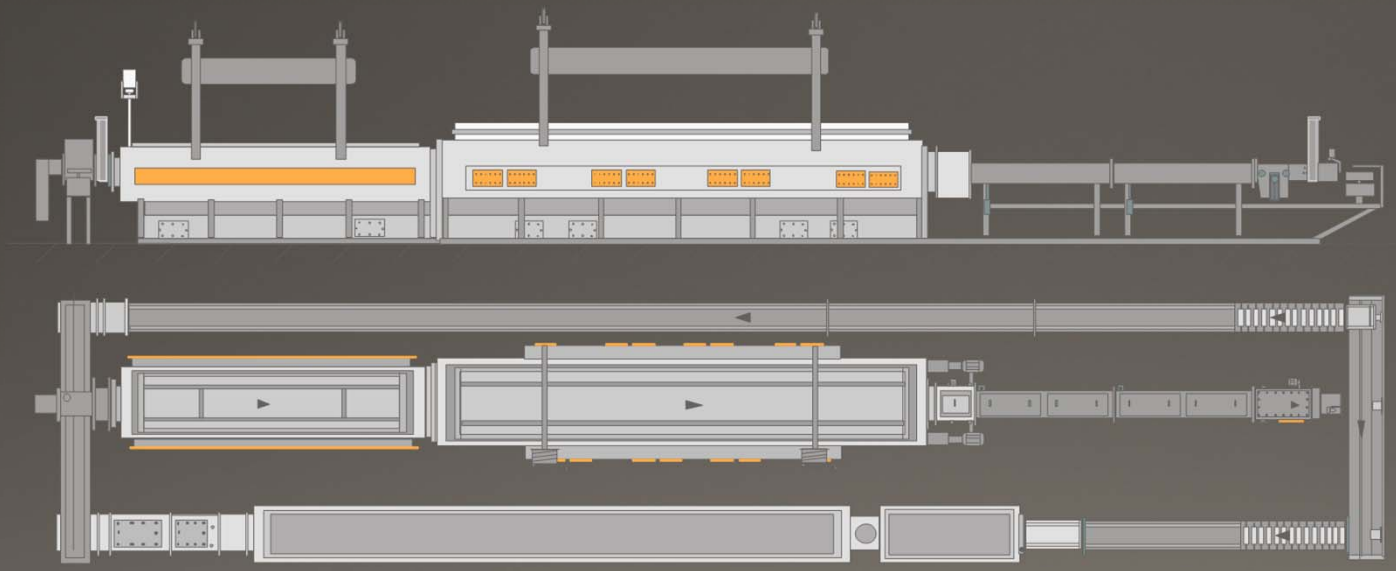
Batch furnace

- Flexibility
- Vacuum capability
- "Lights out" manufacturing
- H2 at partial pressures to 800 mBar
- N2, Ar, H2, Forming Gas, Vacuum
- Laminar Gas Flow
- High Power costs
- Lower Gas Costs
- Titanium process requires Batch furnace

2nd Stage Debind and Sinter

Continuous furnace

- High Volume Output
- Lower Energy costs
- High Gas costs
- High Idling costs



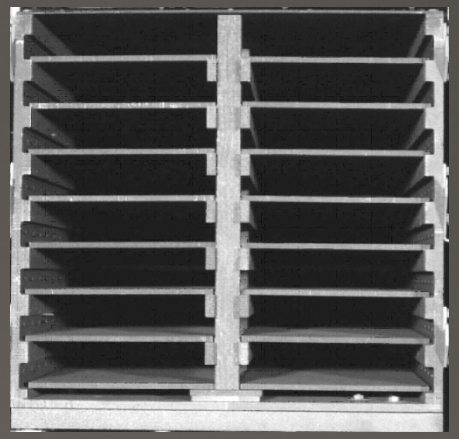
Elnik Retort Integration

- All MIM Debind/Sinter Equipment utilizes the same shelving systems
- Reduces Labor Time – Increases available production time

Catalytic Debind Oven

Solvent Debind Oven

MIM 3000 Series Furnace



GraphMIM Series Furnace

Example - MIM Parts

Photo courtesy of PIM International

Example - Metal 3D Printed Parts

Support Printed into part for post debind and sinter processing

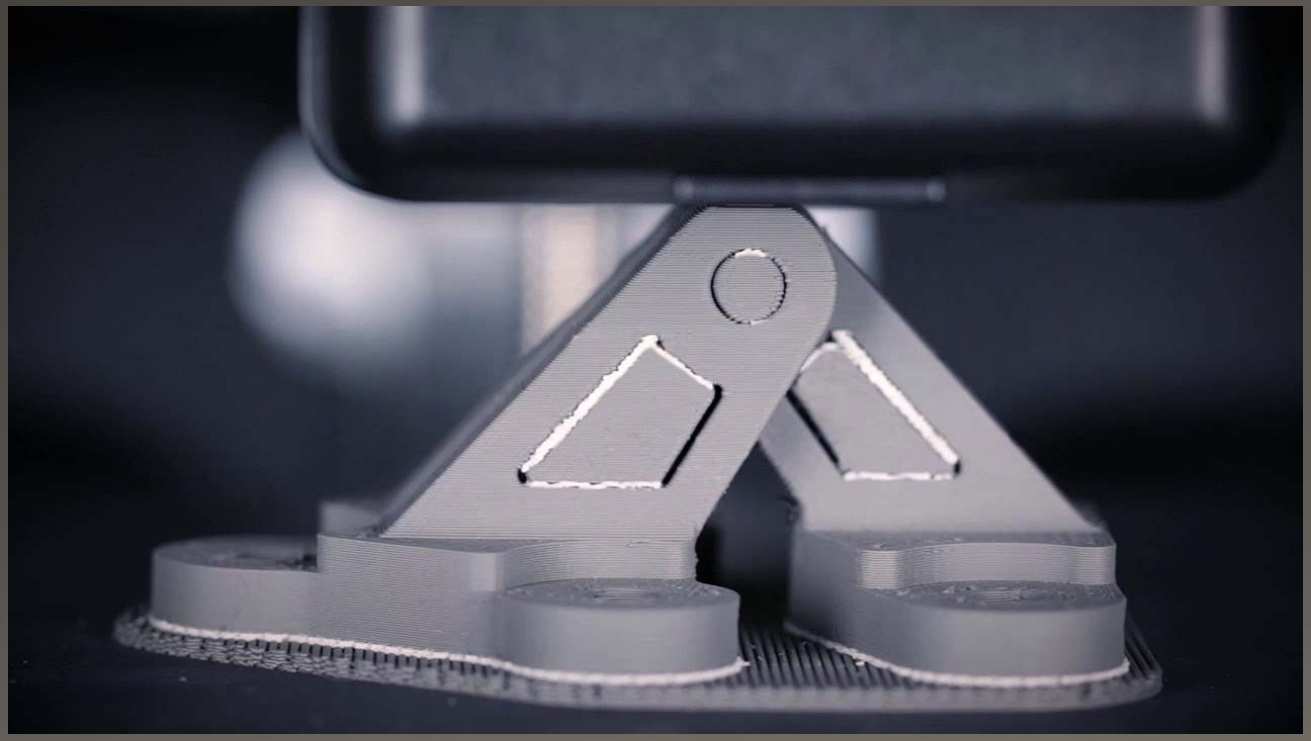


Photo example of Desktop Metal printing process
and Proprietary Anti Sinter Layer

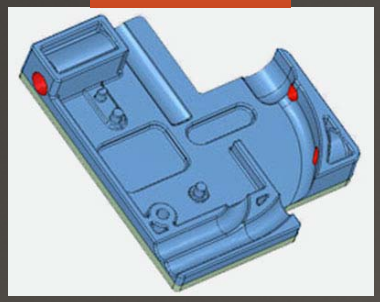
Post Sintering

- Polishing
- Case Hardening
- Threading
- Tight Tolerance Machining
- Coining
- HIP'ing
- Etc…

Staging MIM Parts

- Life cycle of the part through entire process

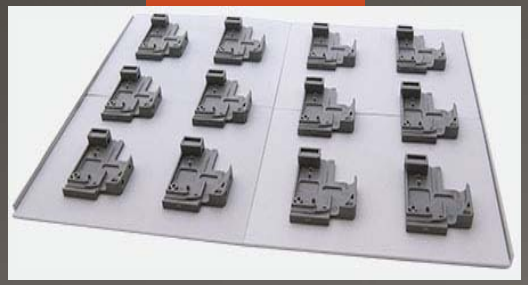
Design



Feedstock

Molding

Staging



Debinding

Sintering

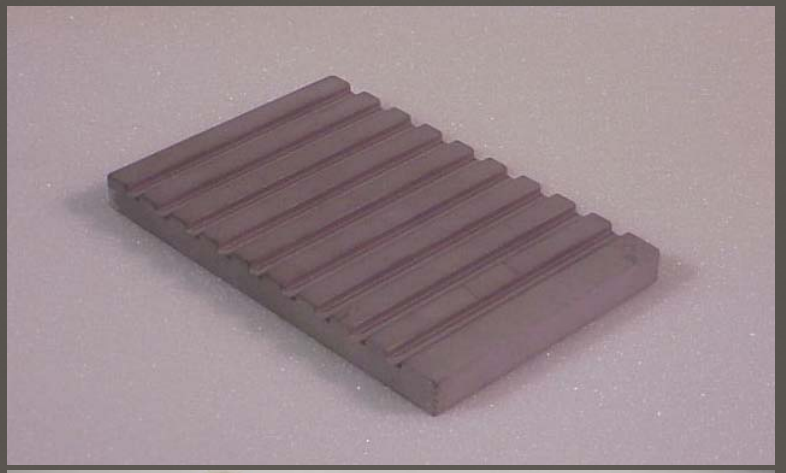
Setter Design

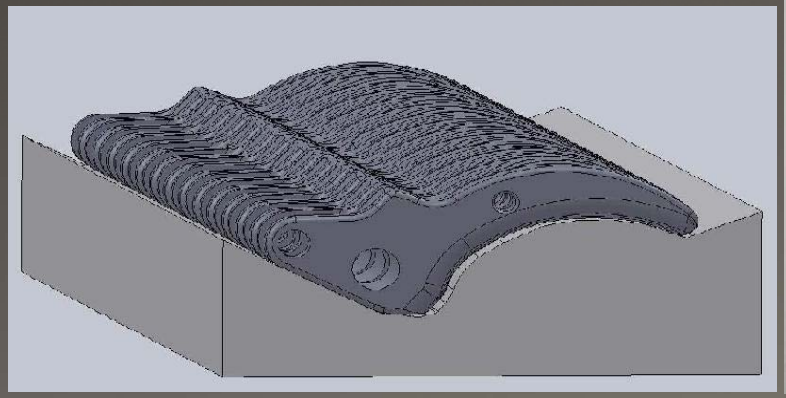
- Flat ceramic trays, dense or porous
- Specially designed ceramic setters to part geometry
  - As Sintered Dimensions
- Injection Molded Setters
  - Ceramic Powders
  - Similar Geometry
- Design of MIM parts needs to include setting principles when applicable

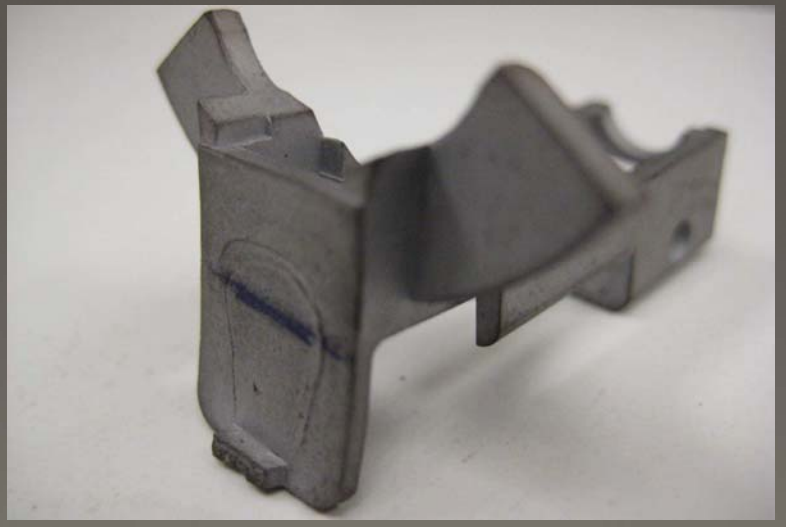
Setter Material

- **AL -** Sintered Alumina, 96% Pure
- **ZTA** – Zirconia Toughened Alumina
  - Micromass
- **YSZ** – Yttria Stabilized Zirconia
  - Titanium
- **PSZ 63** – Calcia/Magnesia Stabilized Zirconia
- **PSZ 01** – Calcia Stabilized Zirconia
  - Titanium
- **PSZ 06** – Magnesia Stabilized Zirconia
- **Porous**
  - Better Gas Flow
- **ZLA**
  - Low Density
  - Machine easy, Dip Coat / Hot Fire sealed
  - Reduced cost special setter design

Setter Examples







Metal 3D Printed Parts

- Staging process is similar to that in MIM
- Challenges
  - High Complex Geometry (Internal structures difficult to support)
  - Designing supports and setters into the part for printing
  - Delamination of print layers
  - Proper print orientation for highest part quality and functionality
  - Standards!!
    - Trade organizations need to drive this
- Extremely high geometric flexibility
  - Many potential doors are opened
- 3D Metal printing leads to Powder Metal Education
  - MIM, Press and Sinter, ETC…

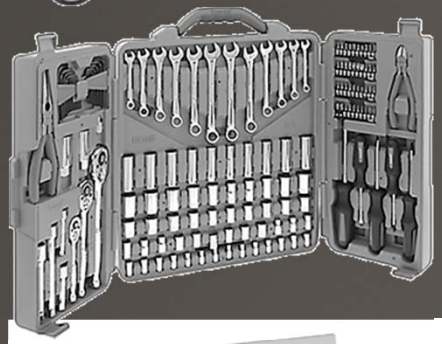
Quality Control

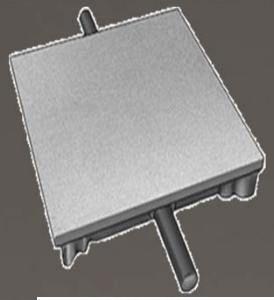
Necessary Laboratory Equipment

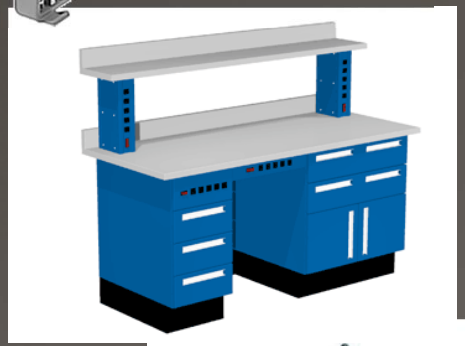
- Helium Pycnometer
- Microscope
- Oxygen
- Carbon
- Scales
- Micrometers and Calipers
- Comparator
- Hardness Tester
- Metallographic Analysis
- Powder Classification

- Quality checkpoints throughout entire process, typically after:
  - Feedstock
  - Injection molding
  - First stage debinding
  - Second stage debinding and sinter


ELTRA CS 800
Carbon Sulfur Determina
PC controlled







DSH TECHNOLOGIES, LLC
YOUR PARTNER IN MIM

- ***Support/ Consulting***
  - *MIM courses*
  - *Part analysis + Process Optimization*
  - *Toll Debind and Sinter + Over Capacity runs*
  - *Turn Key Solutions*
- ***Equipment***
  - *1st stage debinding – Water, Solvent and Catalytic*
  - *2nd stage debinding and sintering – 2 - MIM3045 furnaces, HV, Survey TC's.*
- ***Free DSH Consulting Services***
  - *One Year with the purchase of each new MIM furnace from Elnik*
- ***Try Before You Buy***
  - *Elnik offers 2 Free Trial runs on production sized furnaces at DSH, so long as a MIM furnace is purchased within 1 year of the trial run.*

PGE INJECTION MOULDING LTD

ELNIK SYSTEMS

Why Partner with DSH Technologies?

- Knowledge
- Experience
- NDA's
- Toll Debind/Sinter
- Over Capacity Runs
- R&D work

Customer Testimonials:

"Superb" **"Proficient"**

"Always Fast Reaction Time."

"Good Technical Support, Quick Reply."

"Dr. Satya's experience & interaction helped us to understand the methodology to set sintering parameters for various materials in ELNIK furnace."

"Obtaining guidance from DSH on setter and part design is quite useful to us."

DSH TECHNOLOGIES,LLC
YOUR PARTNER IN MIM

Dr. Satya Banerjee, Chief Engineer of DSH

When we put our "knows" in your MIM business, you'll save a fortune in Time and Money

PGE INJECTION MOULDING LTD

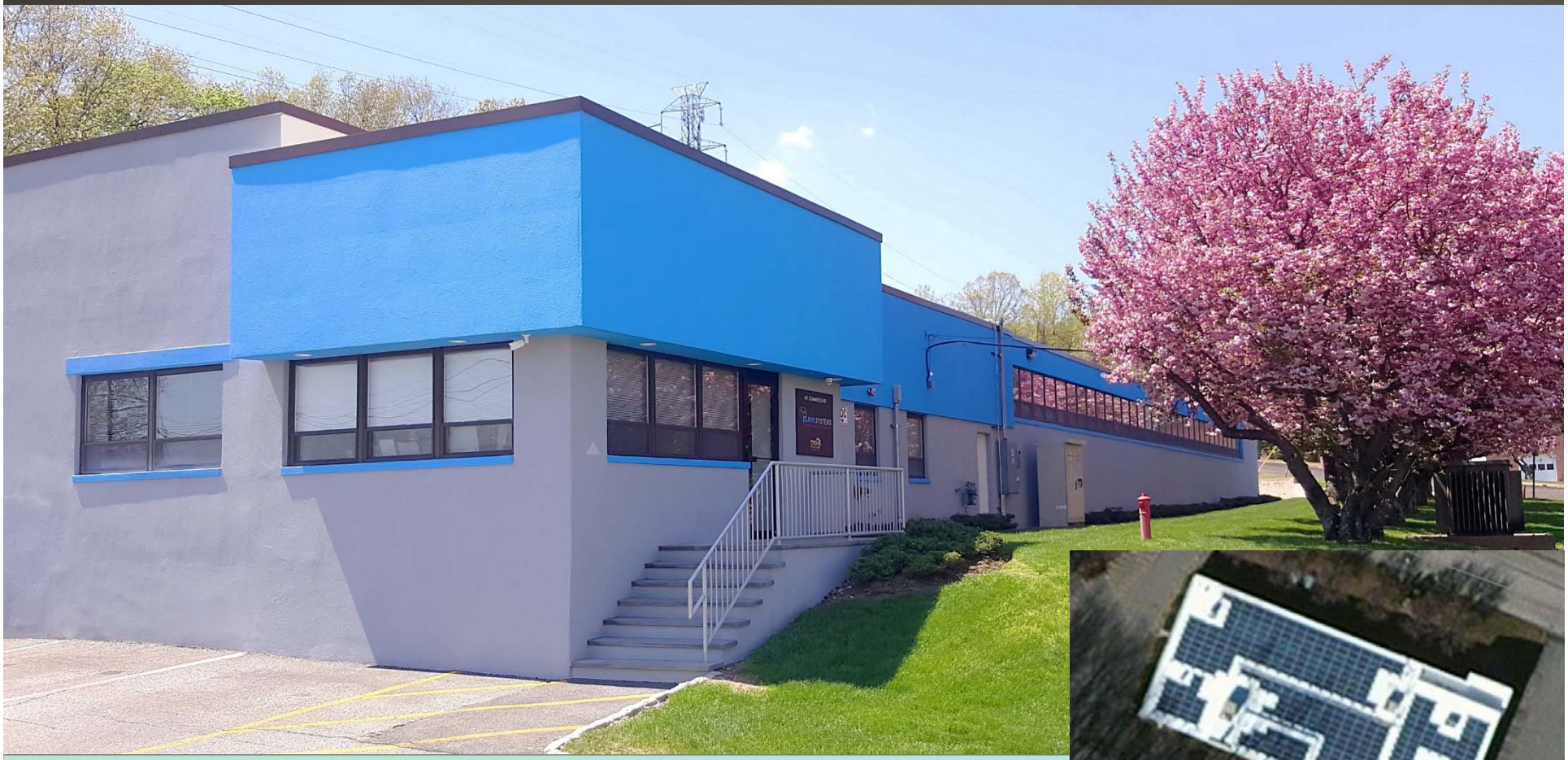
ELNIK SYSTEMS

Useful Links

- PIM International Magazine - http://www.pim-international.com/
- Metal AM Magazine - http://www.metal-am.com/
- PM Review - http://www.pm-review.com/

- Metal Powder Industries Federation - https://www.mpif.org/
- European Powder Metallurgy Association - https://www.epma.com/
- Japan Powder Metallurgy Association - http://www.jpma.gr.jp/en/
- MIMExpertenKreis - http://www.mim-experten.de/en/welcome.html

THANK YOU



Elnik Systems LLC

107 Commerce Road, Cedar Grove, NJ 07009-1207 USA

T: +1 973.239.6066 F: +1 973.239.3272

elnik@elnik.com www.elnik.com