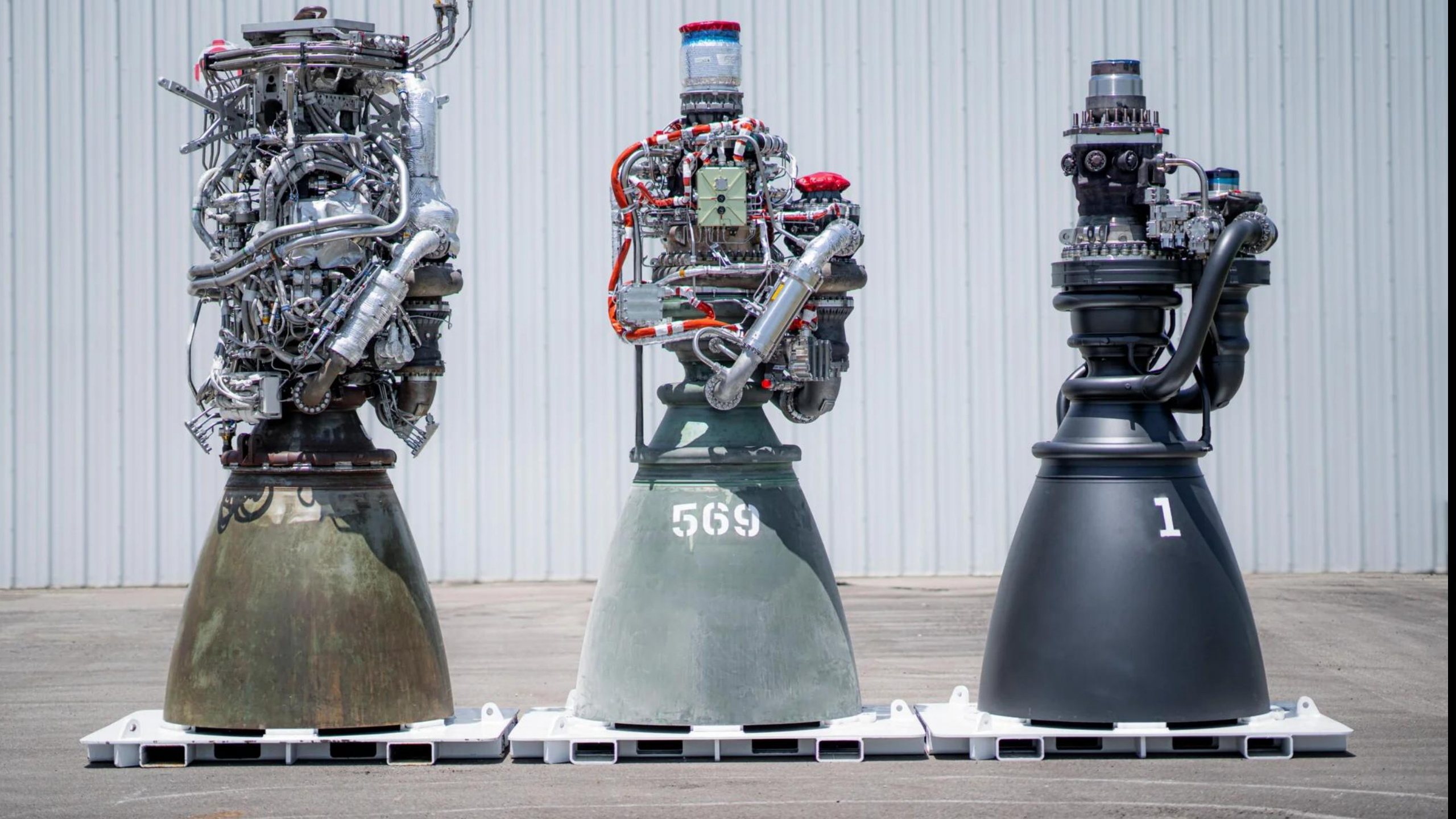

ELEMENTUM
Your AM Materials Expert™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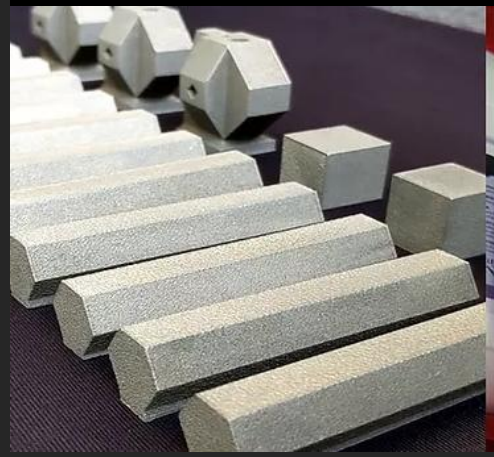
Core Business

High Performance AM metal feedstock powder supply & development.

- AM Process & Application development & qualification

USAF RSO Advanced Manufacturing Olympics Gold Medal winning A7050-RAM2 Alloy



Powering the Next Frontier

MARS PERSEVERANCE ROVER

Aluminum 6061-RAM2

FORMULA 1 RACING

Aluminum 2024-RAM2

POWER & ENERGY

Nickel IN625-RAM2 & Ni230-RAM1

PROPULSION & DEFENSE

Copper, Nickel, & Aluminum RAM

Elementum 3D Facilities & AM Equipment

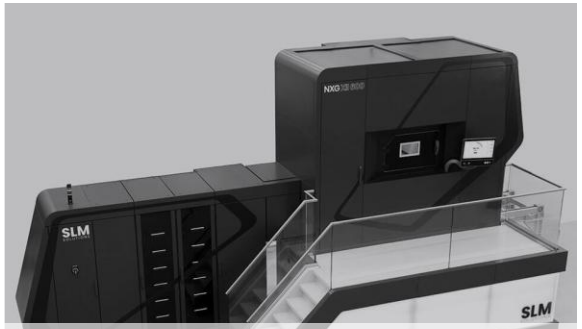
Erie, Colorado, United States

HEADQUARTERS

DEDICATED DEVELOPMENT PRINTING CAPACITY

- Founded in 2014
- 27 Technology Patents
- 44 Employees
- 220+ customers
- 400 ton annual capacity

SLM 280 PRINTER



SLM NXG XII 600 PRINTER

2ND FACILITY

ADVANCED ALUMINUM ATOMIZATION (SOON)

LARGE CAPACITY RAM POWDER PRODUCTION

TON-SCALE POWDER LOTS

ISO 9001-2015 Certified
AS9100
DFARS/NIST 800-171
ITAR Registered
Federal Firearms License Lvl. 10

METALLURGICAL LAB

Our History

2014-2016

- Founded by Dr. Jacob Nuechterlein, CEO.
- Filed RAM technology patents together with Dr. Jeremy Iten, CTO.
- Introduced world's first AM metal matrix composite commercial feedstock.
- NASA is first customer.

2017-2019

- Formnext Start-up Challenge winner.
- First DoD and NASA programs launched.
- Patents granted domestically and internationally.

2020-2022

- First aluminum composite rocket engines successfully hot-fired using A1000-RAM10.
- Nickel superalloys and copper alloys developed with NSF and NASA support.
- Funding round drives vertical integration.
- Powder production grows to a capacity of 400 tons/yr.

2023

- E3D materials help win F1 race in first use.
- 4 additional F1 teams qualifying F1 rulebook specified Elementum 3D aluminums.
- $10M+ in ongoing government contracts focused on development, qualification, and application of Elementum 3D materials.

2024+

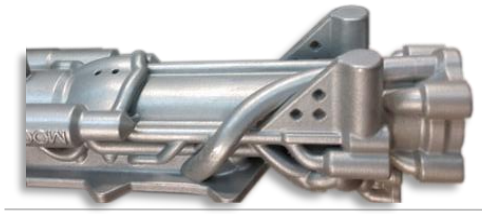
- Reach 100+ tons production.
- Automated agile atomizer online.
- MMPDS design allowable datasets for FAA allowance in commercial aviation.
- New products for aero/space, energy, and semiconductor manufacturing.

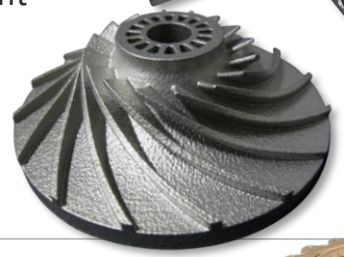
Elementum 3D Materials

RAM Aluminum Alloys

1000 | 2024 | 5083 | 6061 | 7050

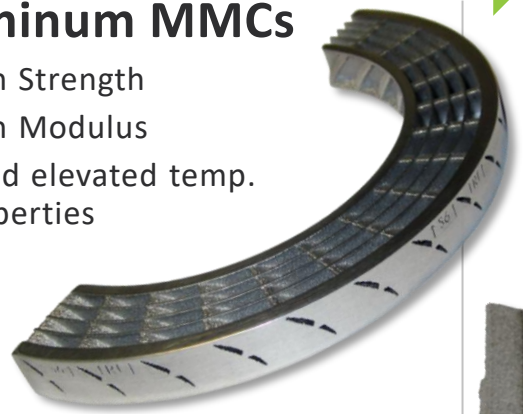
- Properties matching wrought
- Heat treatable like wrought





Aluminum MMCs

- High Strength
- High Modulus
- Good elevated temp. properties



RAM Nickel Alloys

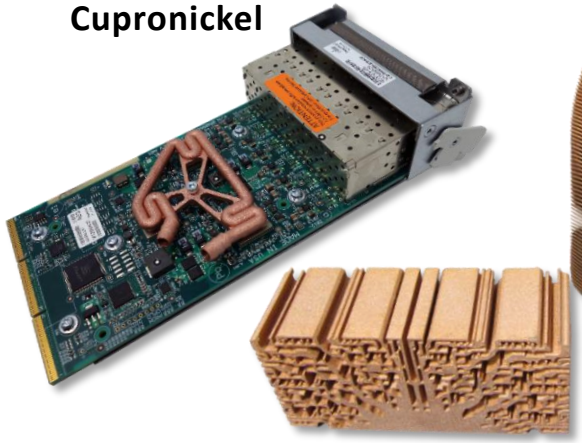
Ni230| IN625 | GRX-810 | Invar 36

- High temperature strength and creep resistance
- Corrosion and oxidation resistance

Copper Alloys

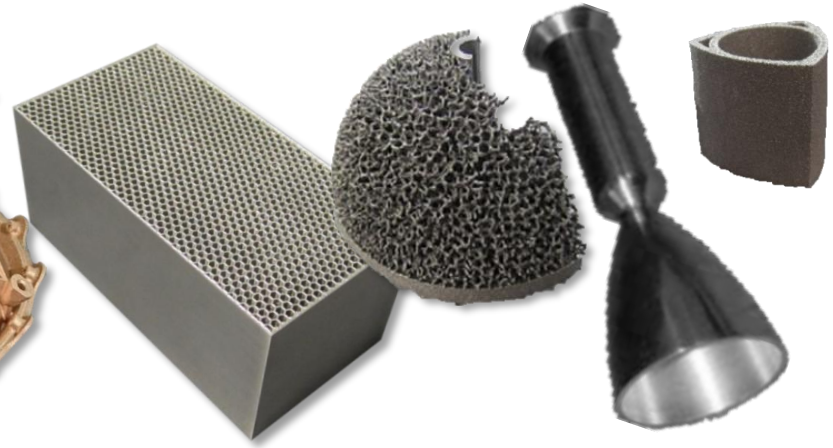
Cu-100 | Cu-Al Bronze | GRCop-42

Cupronickel



Refractory Metals

Tungsten | Tantalum | Rhenium | Molybdenum



Steels

RAM Steel | E185 | W360

Reactive Additive Manufacturing (RAM)

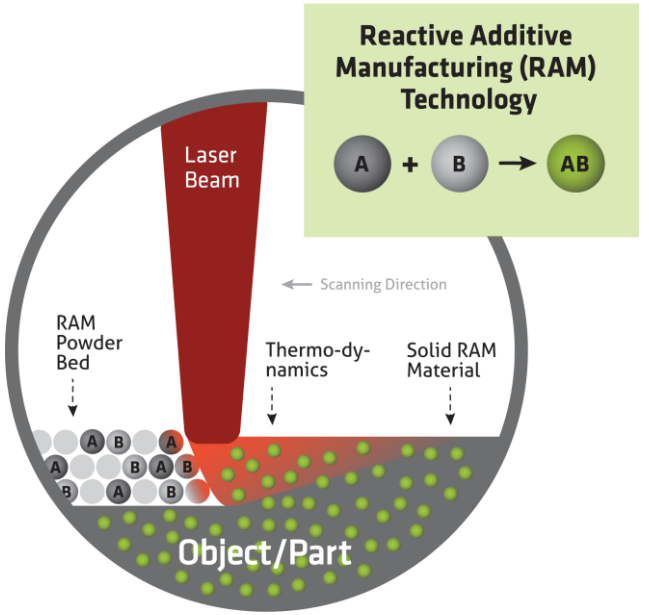
Patented Technology

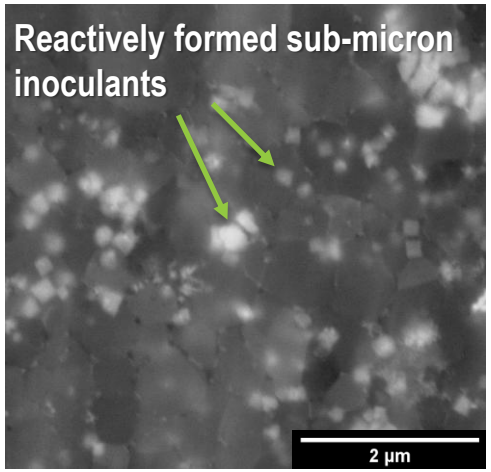
Reaction synthesis inspired

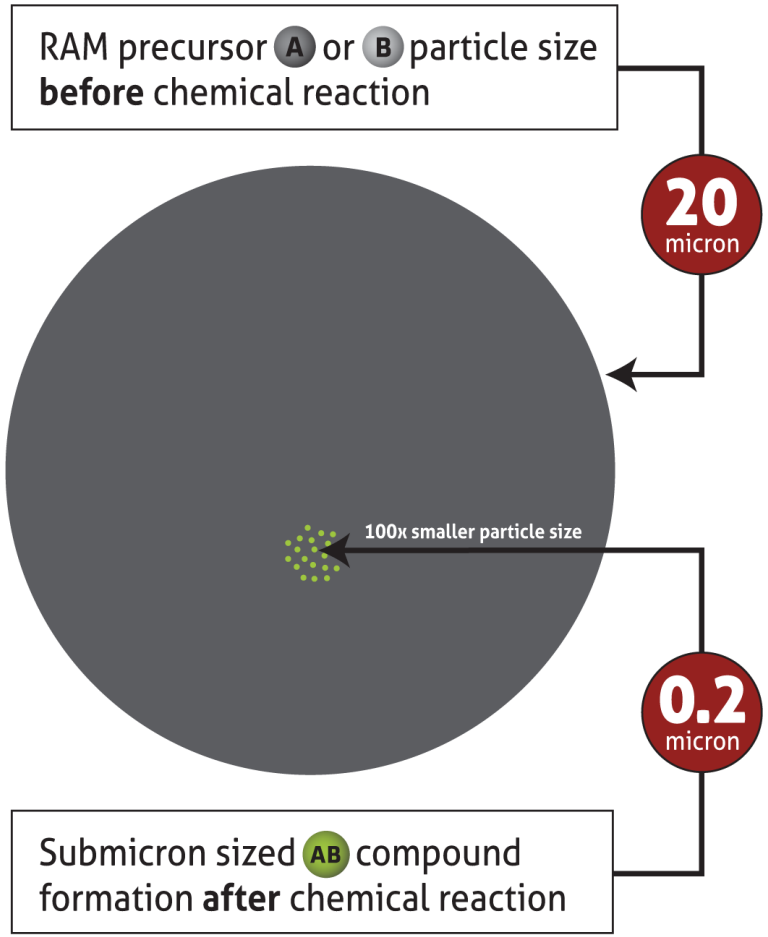
- Product phases are formed in situ through energetically favorable reactions
- Enables use of traditional AM **(micron) sized reactant powders** while forming submicron **(nano) products** in solid parts
- Enables use of reactant species with lower melting temperatures than product species to promote **full density parts**
- Particulates improve strength, elevated temperature performance, wear resistance, and reduce CTE
- Tailorable properties

Makes unprintable metals printable!

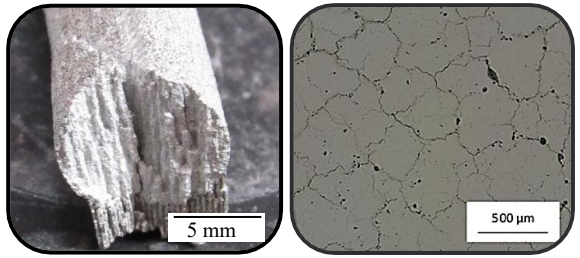
- Eliminates hot tearing by forming sub-micron heterogeneous nucleation sites for fine equiaxed grains



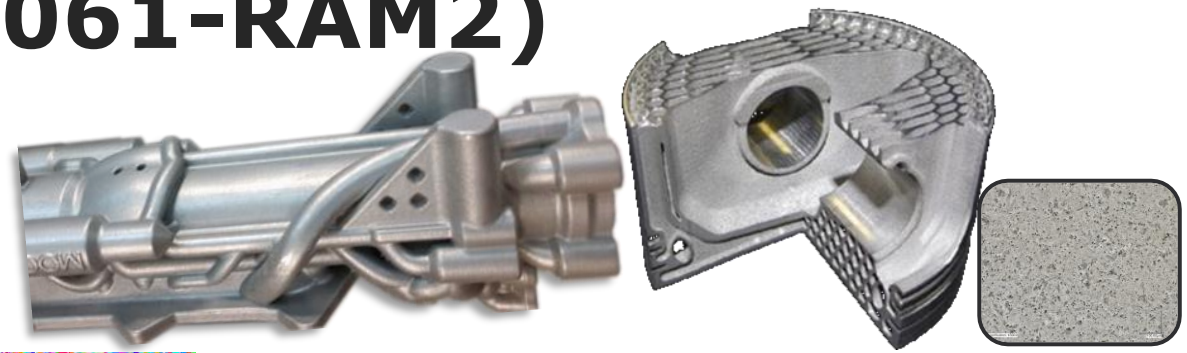




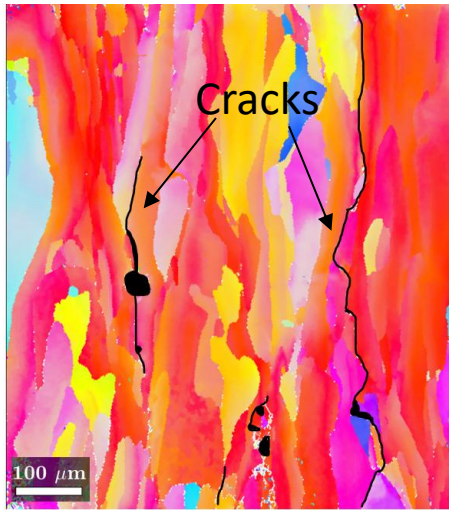
Refinement with RAM (A6061-RAM2)



RAM Inoculation



Build Direction

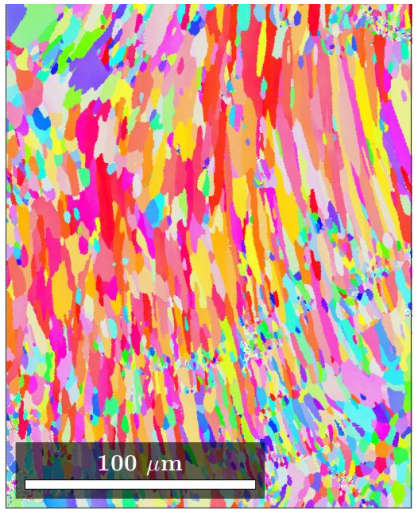


Legacy Alloy

Grain size:

100s of µm to mm

Note: lower magnification.

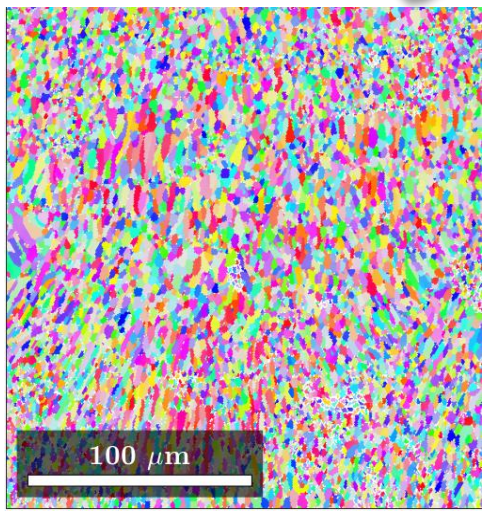


RAM 0.5

Grain size:

Area: 8.87 µm^2

Diameter: 4.37 µm

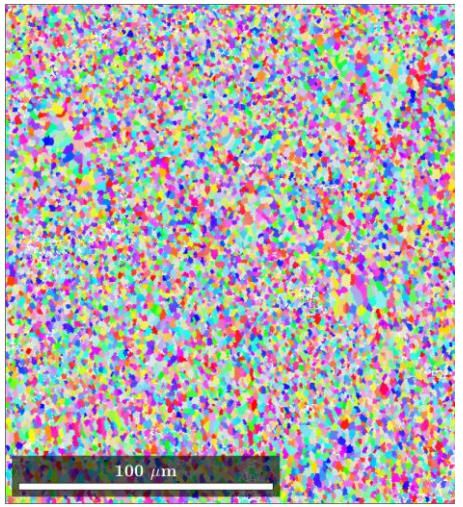


RAM 1

Grain size:

Area: 3.84 µm^2

Diameter: 2.80 µm

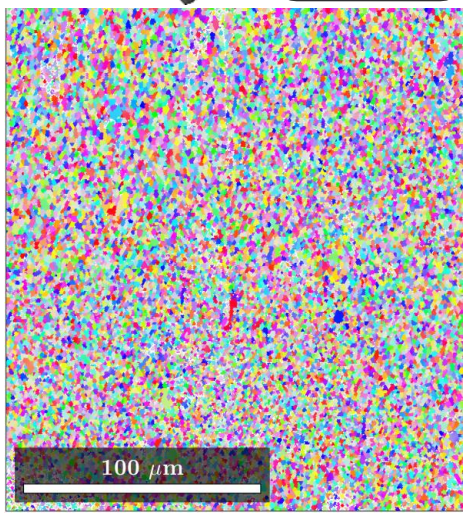


RAM 2

Grain size:

Area: 1.91 µm^2

Diameter: 1.93 µm



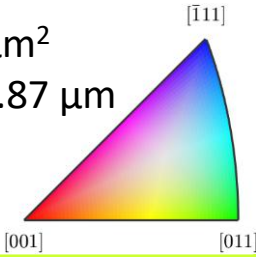
RAM 10

Grain size:

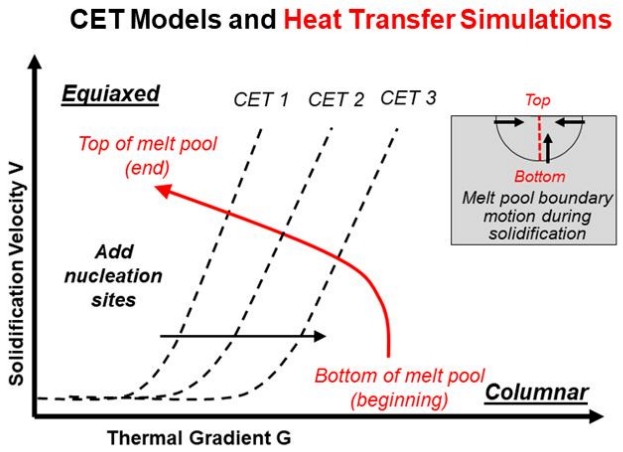
Area: 1.74 µm^2

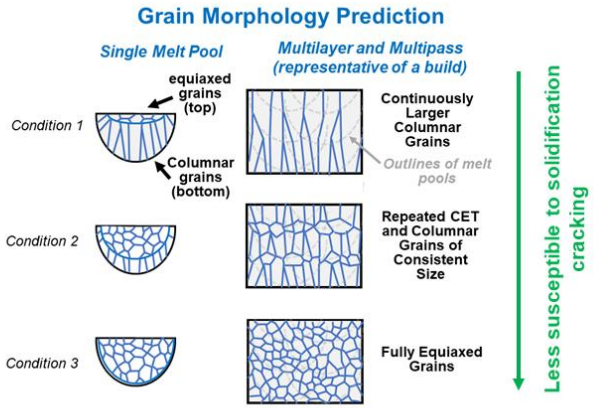
Diameter: 1.87 µm

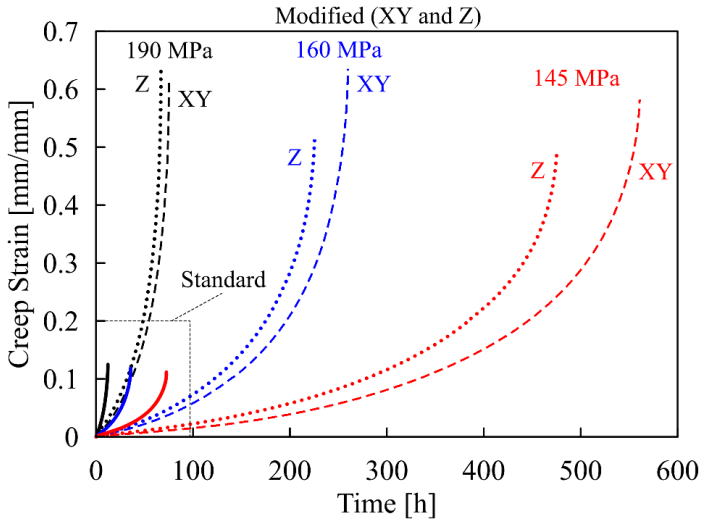
Increasing RAM Content

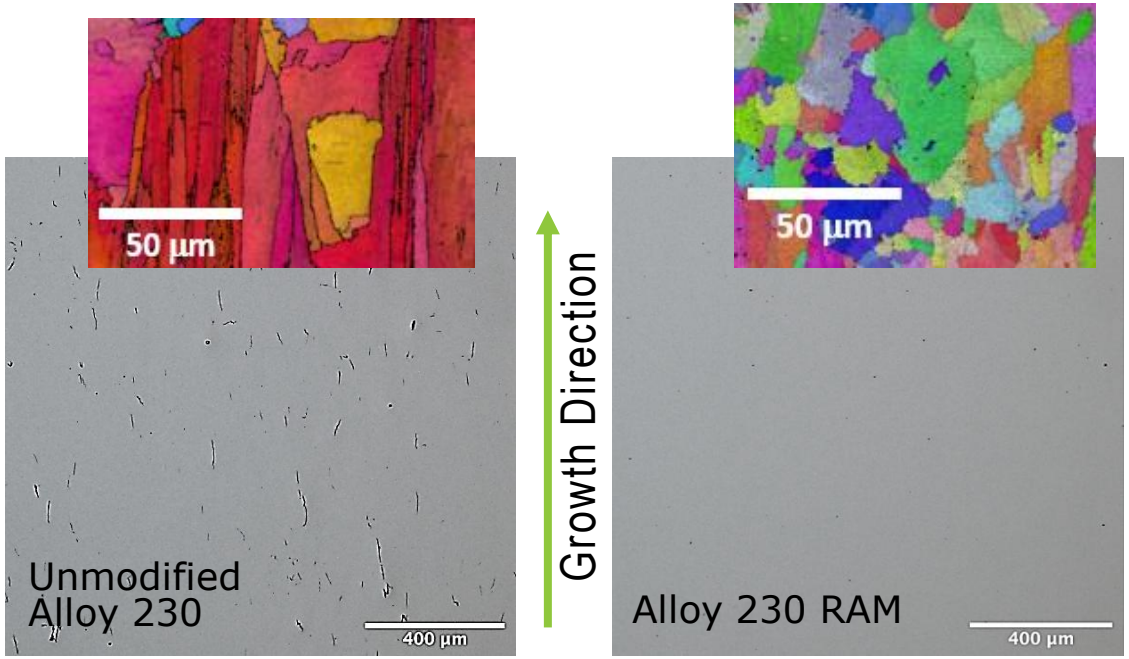


RAM Nickel Superalloys
e.g. Alloy 230





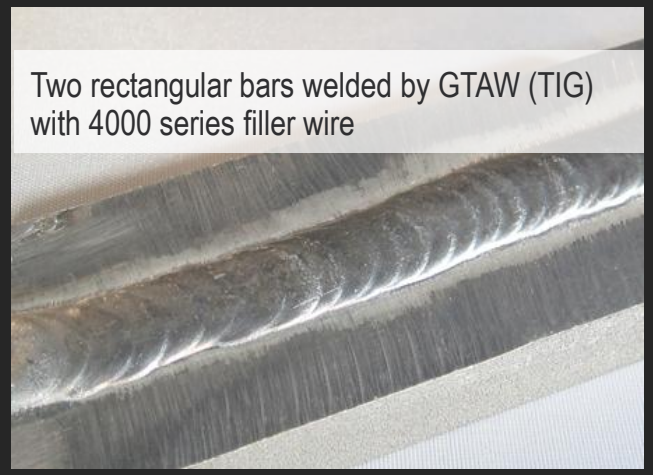




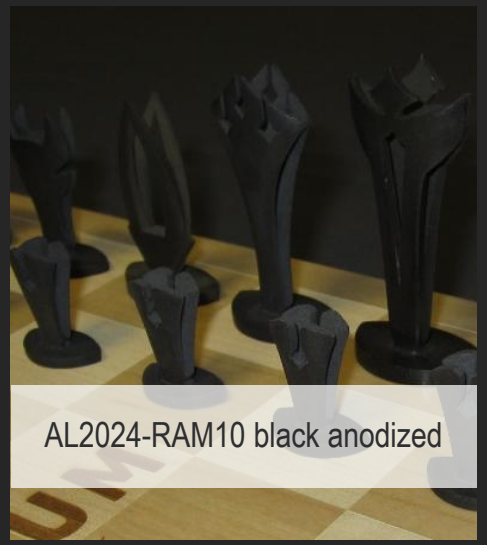
Utilized ICME framework with RAM to explain and solve microcracking and improve properties.

- Y.S. 60% greater than wrought Alloy 230 at 1400°F (760°C)
- Elongation ~6X higher than unmodified LPBF Alloy 230
- Vastly improved creep compared to unmodified LPBF Alloy 230

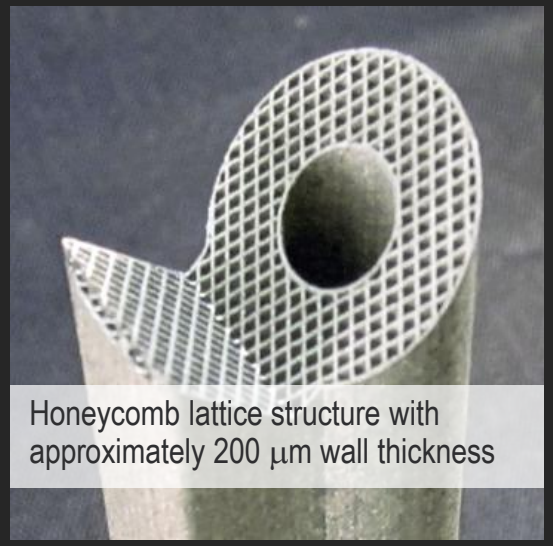
Finish and Post Processing



Two rectangular bars welded by GTAW (TIG) with 4000 series filler wire



AL2024-RAM10 black anodized



Honeycomb lattice structure with approximately 200 µm wall thickness

A6061-RAM2

- Upskin Ra = 4 µm
- Downskin Ra = 6 µm

As printed surface
(Part Designed by Moog)

Chromated A6061-RAM2 Parts and photos by Ball Aerospace

Chemical machined A6061-RAM2 aerospike nozzle

FORTIUS METALS

Enabling the W-DED industry

With a unified suite of product offerings

RAM Wire Materials

Producing advanced welding wire for traditional welding and W-DED

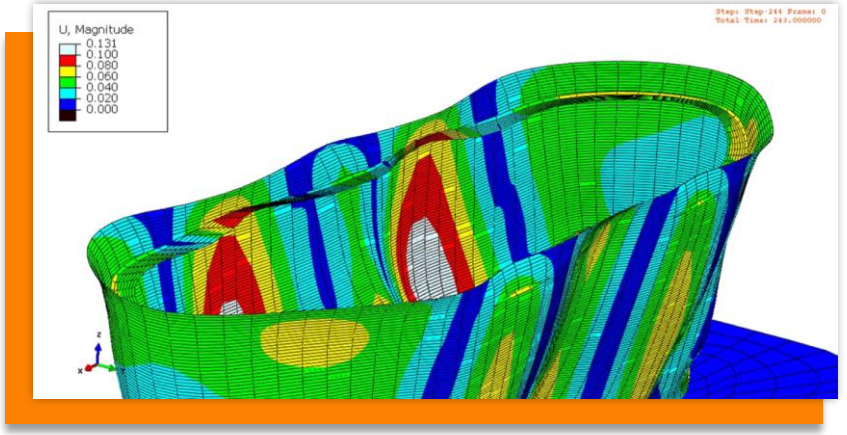
- A6061-RAM2 commercial
- A7075-RAM2 funded development
- GrCop42 funded development
- IN625-RAM2 funded development
- SS316L-RAM funded development
- A2024-RAM2 IRAD
- A5083-RAM5 IRAD

Manufacturing

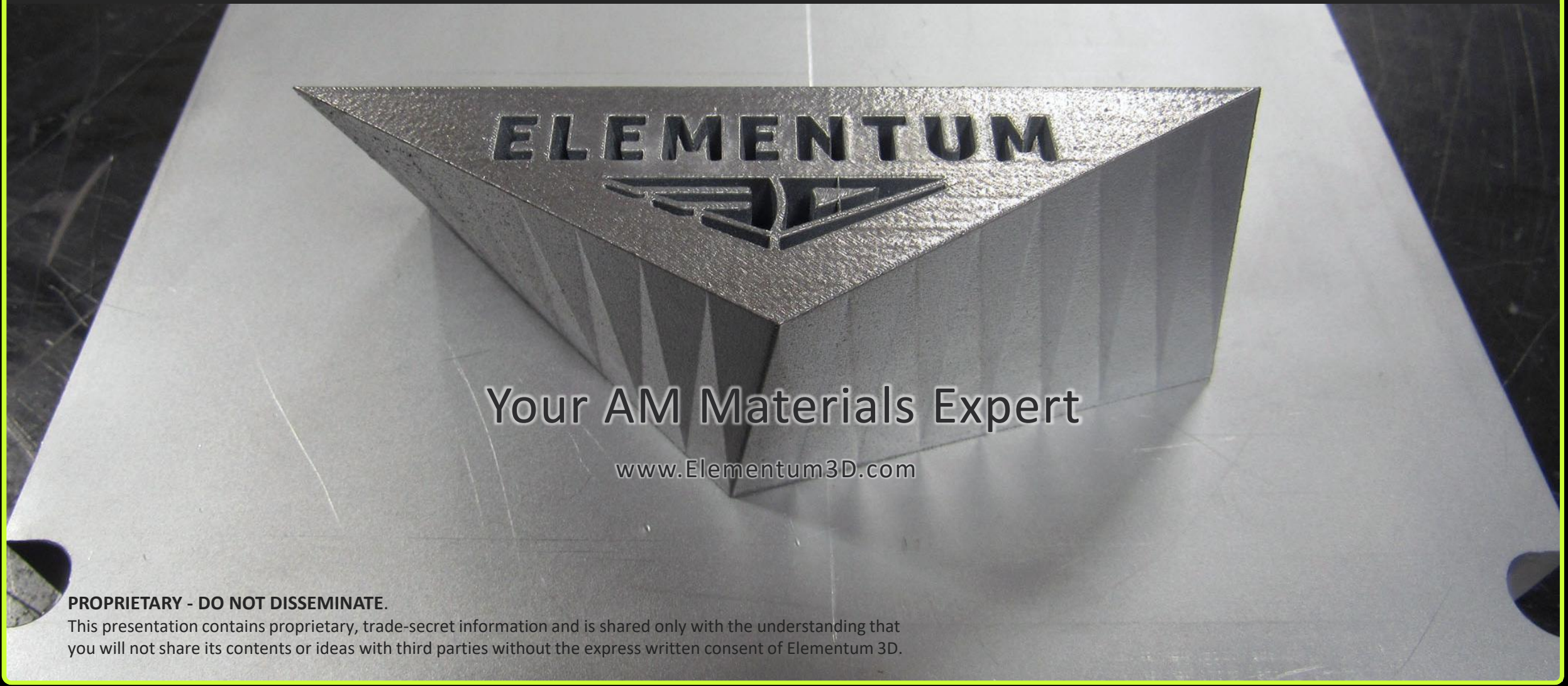
Wire-arc and Wire-laser DED fabrication in-house using Fortius' advanced controls.

Simulation

Custom physics-based simulation software for advanced W-DED CAM



Questions



PermiAM

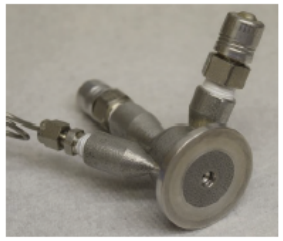
Controlled permeability for fuel injection, heat pipes, and more.

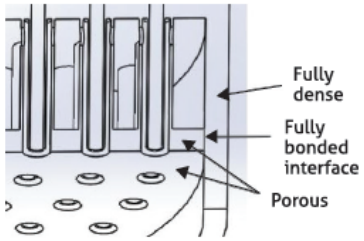
“I can’t overstate how much this technology is an absolute game changer for us.”

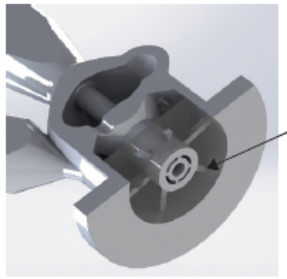
- NASA Propulsion Engineer

CASE STUDY - INJECTOR DESIGN

Test data shows PermiAMcan lower injector face temperature from 530°F to 141°F, a 389°F decrease with 5.6% fuel mass flow.



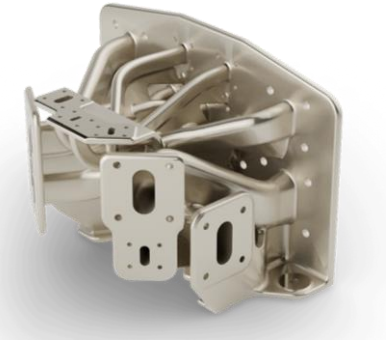




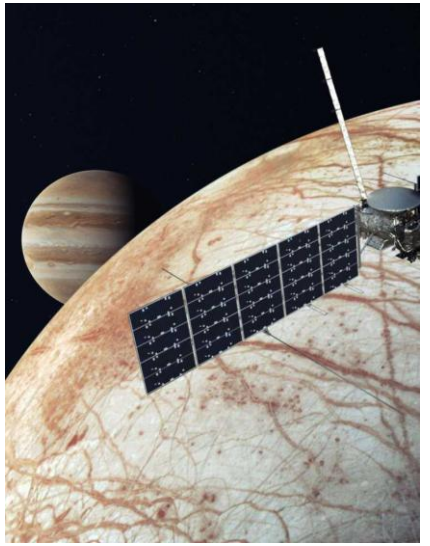
Significance & Test Results

- Lower cost engine development and production.
- AM injector designs with face cooling & chamber wall cooling.
- Novel engine designs to increase performance.
- Increased engine stability: dampen acoustic instabilities.
- No low cycle fatigue issues observed during hot fire testing.
- Lower injector thermal stress: test data shows injector face at 41-50°F internal with 141°F face temperature during steady state hot fire.

Selected Programs



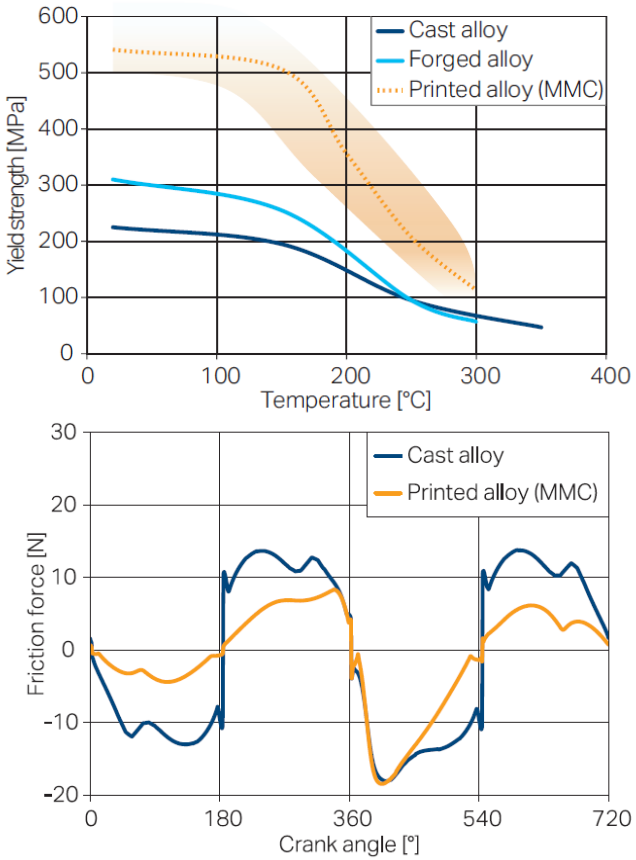
- NAVSEA
  - STTR - Additive manufacturing of High-Performance Copper-Based Components and Materials
- Air Force
  - AF Rapid Sustainment Office – Qualification of A6061-RAM2
  - AFRL through America Makes – Qualification of A7050-RAM2
- Army AAL
  - AM of Javelin, Stinger, and GMLR
- NASA
  - A6061-RAM2 – Qualified to NASA-STD-6030. First ever fully qualified AM parts were launched on Europa Clipper.



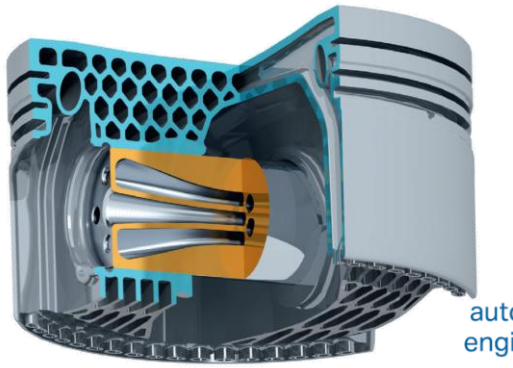
CASE STUDY

RAM Aluminum Combustion Engine Pistons

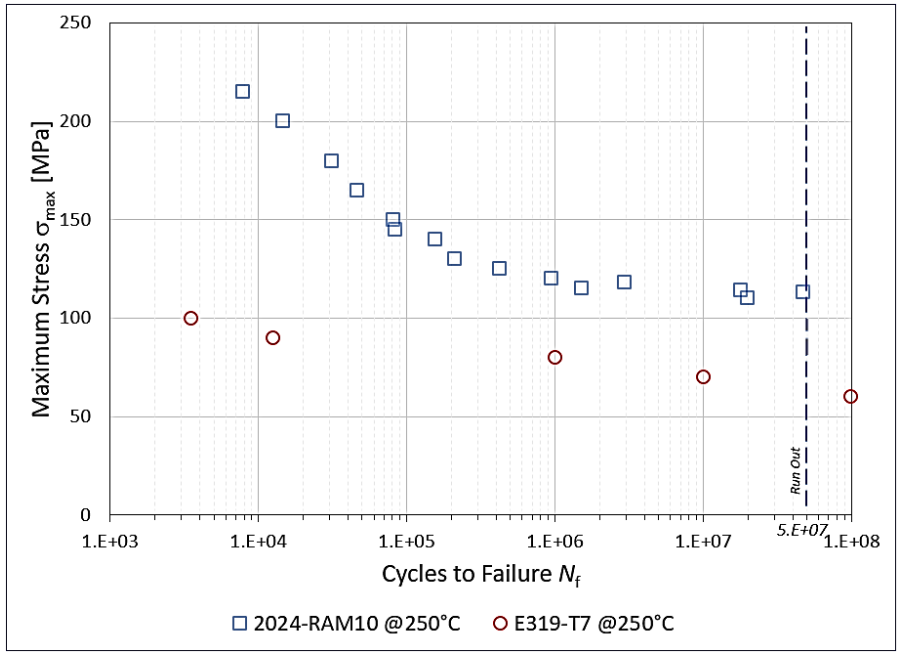
- Strong and light weight material. AM design optimized for **reduced inertial forces.**
- Reduced CTE and low coefficient of friction from MMC for **reduced friction**.
- **Higher performance and fuel efficiency**
- Excellent strength and fatigue life at temperature for **longer service life.**



Friction reduction of the piston skirt by materials with reduced thermal expansion

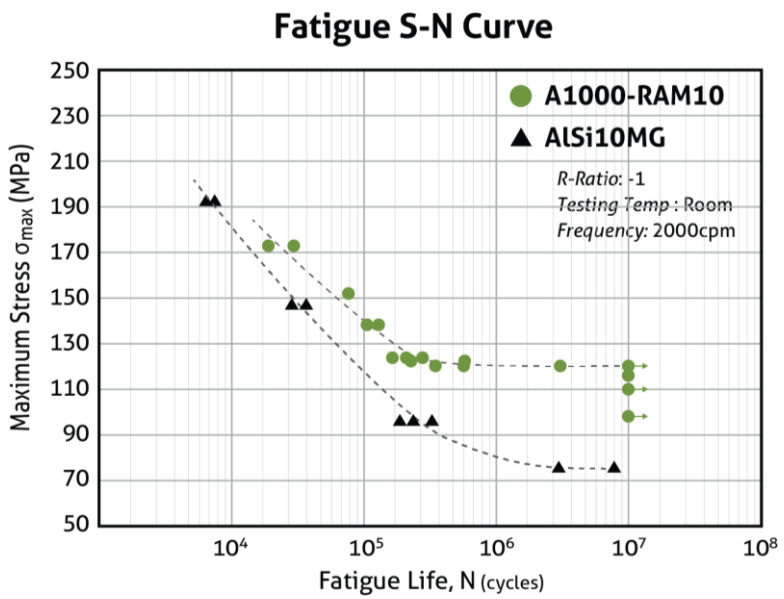


automotive engineering iav

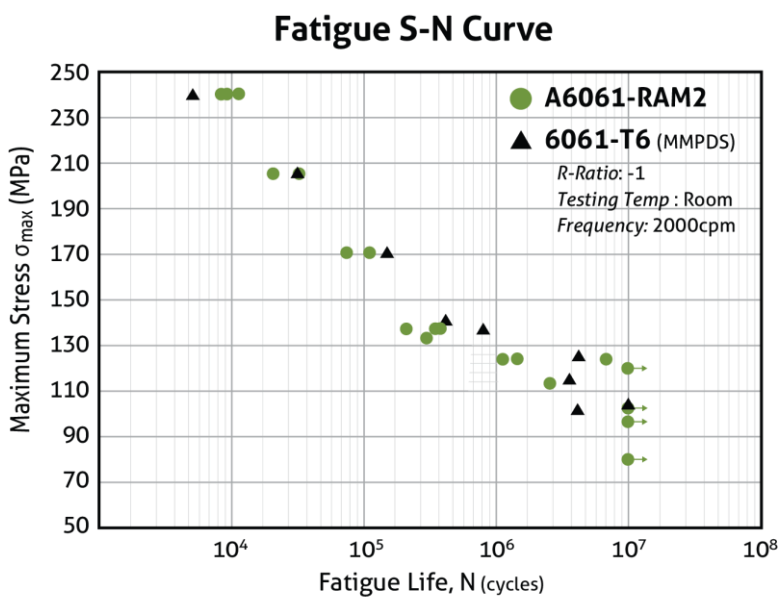


RAM Aluminum Fatigue Data

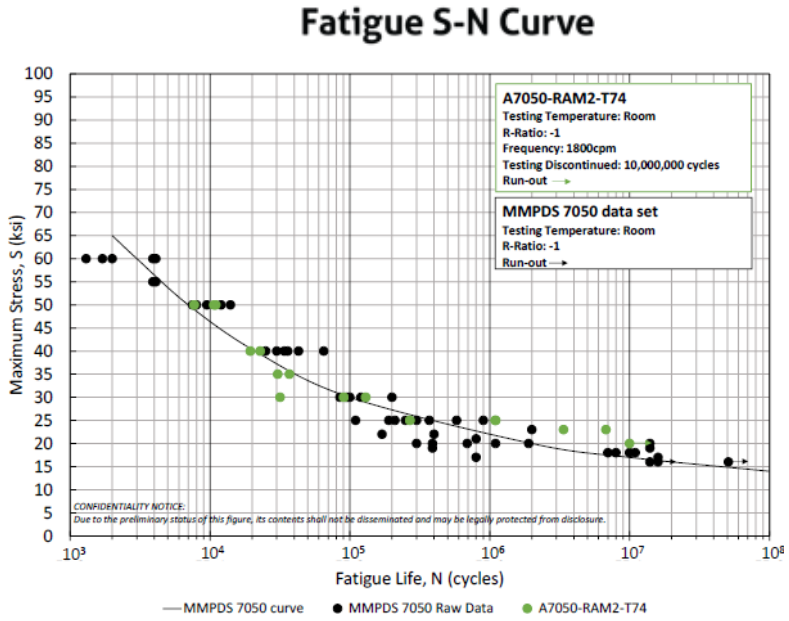
A1000-RAM10



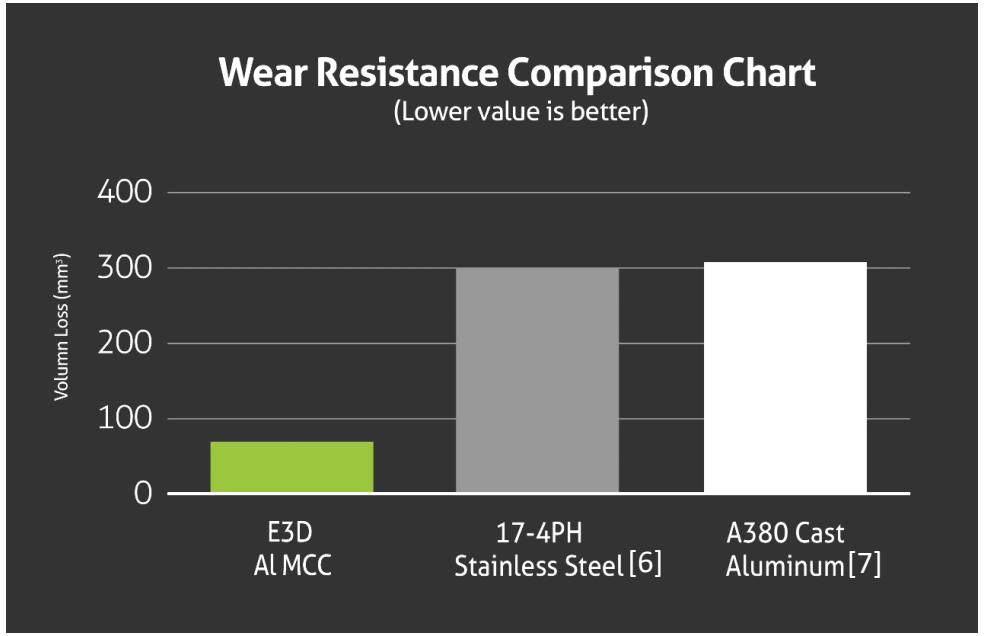
A6061-RAM2



A7050-RAM2



RAM Aluminum Composites

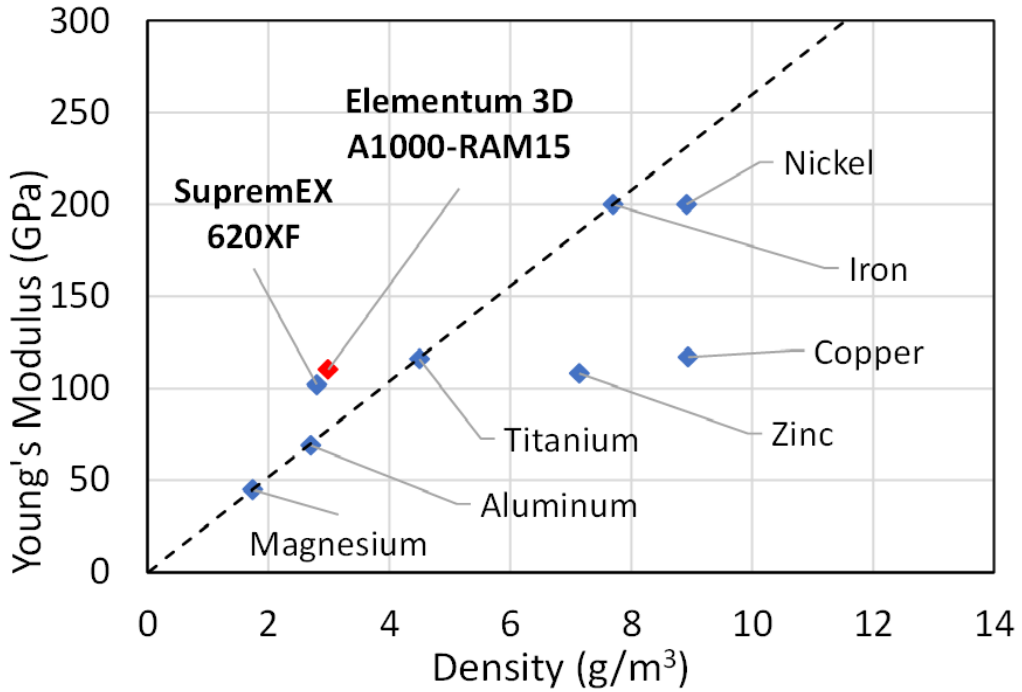


ASTM G65 Procedure E material volume loss for printed AL2024-RAM10 compared to traditionally produced alloys.

[6] Suthar et al. (2015). Comparative evaluation of abrasivewear resistance of various stainless steel grades. *GE- International Journal of Engineering Research, 3*(7)
[7] Lall and Williamson. Wear Resistance and Mechanical Properties of Selected PM Aluminum Alloys and Composites, Metal Powder Products Company

High Specific Stiffness

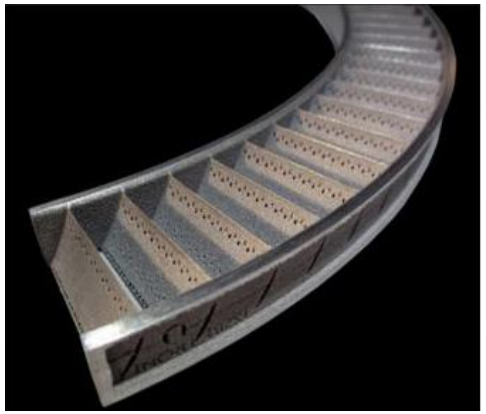
- Al-MMCs are a candidate for replacement of beryllium composites (e.g. Flight electronics housings)



Wrought properties: Matweb.com

Properties of AL2024 and AL6061

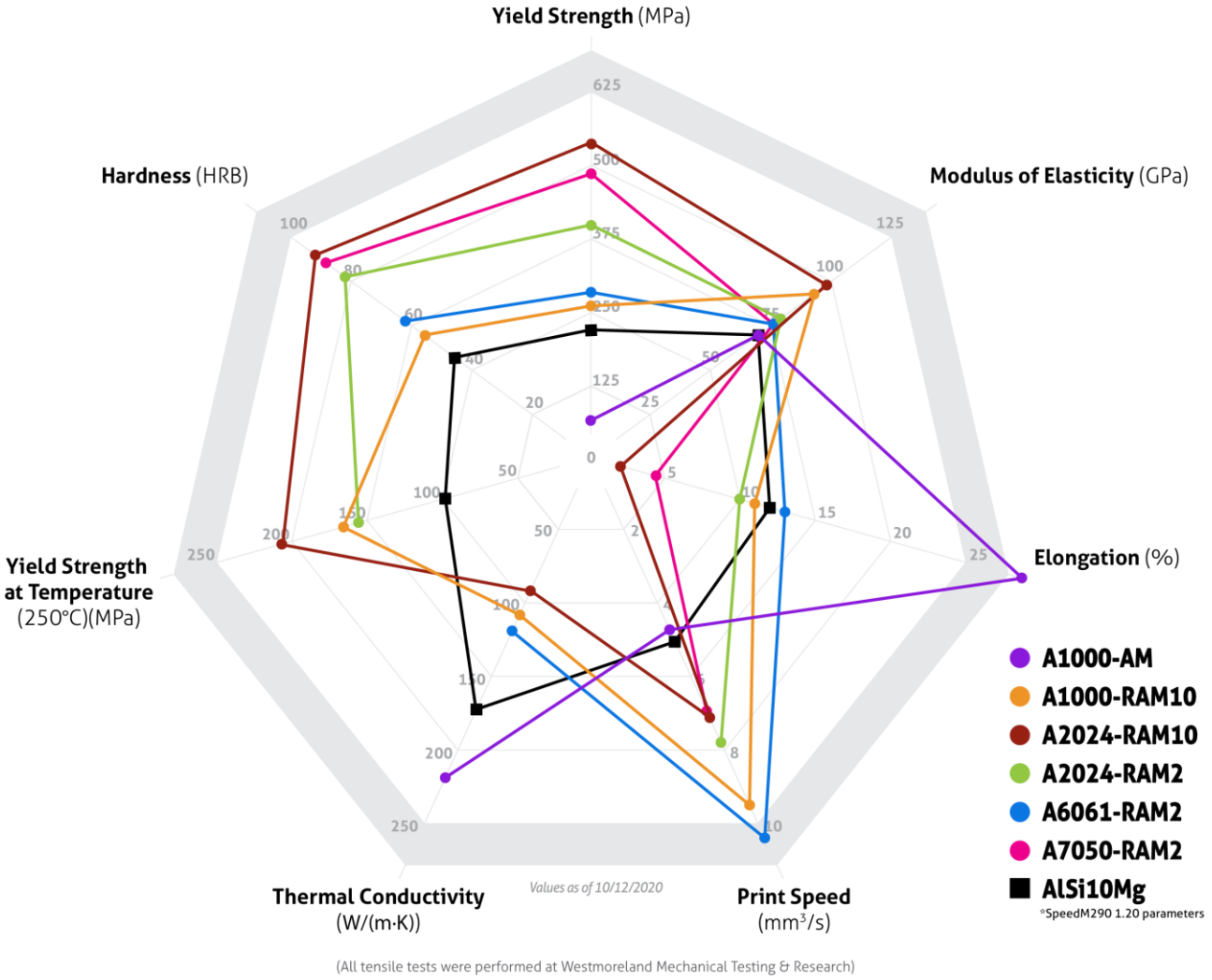
Properties	Wrought AA2024-T6	A2024-RAM2-T6	A2024-RAM10-T6
Density (g/cm^3)	2.78 (typical)	2.82	2.97
Hardness (HRB)	78 (typical)	82±3	92±3
Yield Strength (MPa)	345 (min)	400	535
Tensile Strength (MPa)	427 (min)	496	555
Elongation (%)	5% (min)	10	2
Modulus of Elasticity (GPa)	73 (typical)	79	98



Properties	Wrought Al6061-T6	AL6061-RAM2-T6	AL6061-RAM10-T6
Density (g/cm^3)	2.7 (typical)	2.73	2.89
Hardness (HRB)	60 (typical)	62	79
Yield Strength (MPa)	241 (min)	285	308
Tensile Strength (MPa)	262 (min)	315	421
Elongation (%)	8% (min)	13	6
Modulus of Elasticity (GPa)	69 (typical)	76	97

Elementum 3D Aluminums

Elementum 3D AM Aluminum Materials
(Compared to AlSi10Mg)



(All tensile tests were performed at Westmoreland Mechanical Testing & Research)

RAM Technology

Reactive Additive Manufacturing (RAM)

RAM Powders
+ Thermodynamics

Advanced Composites

Laser Powder Bed Fusion 3D Printing Process