CARPENTER TECHNOLOGY

July 2025

Paris Air Show

Lighter, faster, stronger metallurgy for defense

The first line of defense

MISSION-CRITICAL METAL

Built to weather the storm: on land and sea, in air and space, in wars and in between.

Our military-grade, American-made alloys have been THE standard for defense contractors for 135 years.

WE HAVE YOUR BACK

Carpenter Technology Defense market team

120 combined years of experience in the U.S. specialty metals industry

Vic Talotta
Global Aerospace and Defense

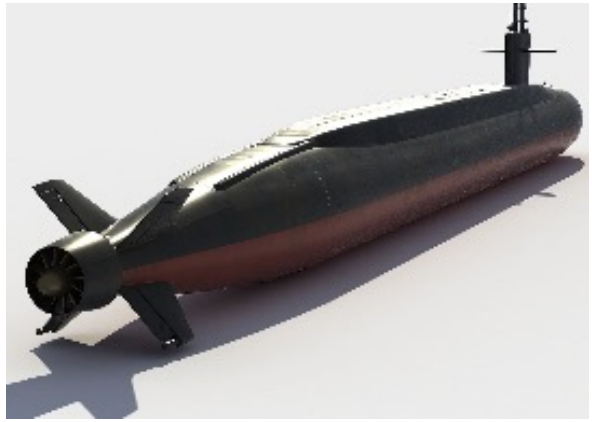
Colleen Tomasello
Defense R&D

Humberto Raposo
Application Metallurgy Defense

Dan Roup
Defense Marketing

OVERVIEW

We support applications and platforms across the Defense landscape



Our **200+ metallurgists** constantly innovate stronger, tougher, more corrosion-resistant alloys

Carpenter Technology: A global leader in specialty materials solutions

135+ years
of innovation in specialty alloys

~$2.8B sales
5,000+ Employees

Global presence
Sales, distribution, manufacturing

Product forms

1. Ingot / Billet
2. Strip
3. Wire
4. Bar
5. Powder
6. Components

Alloy portfolio

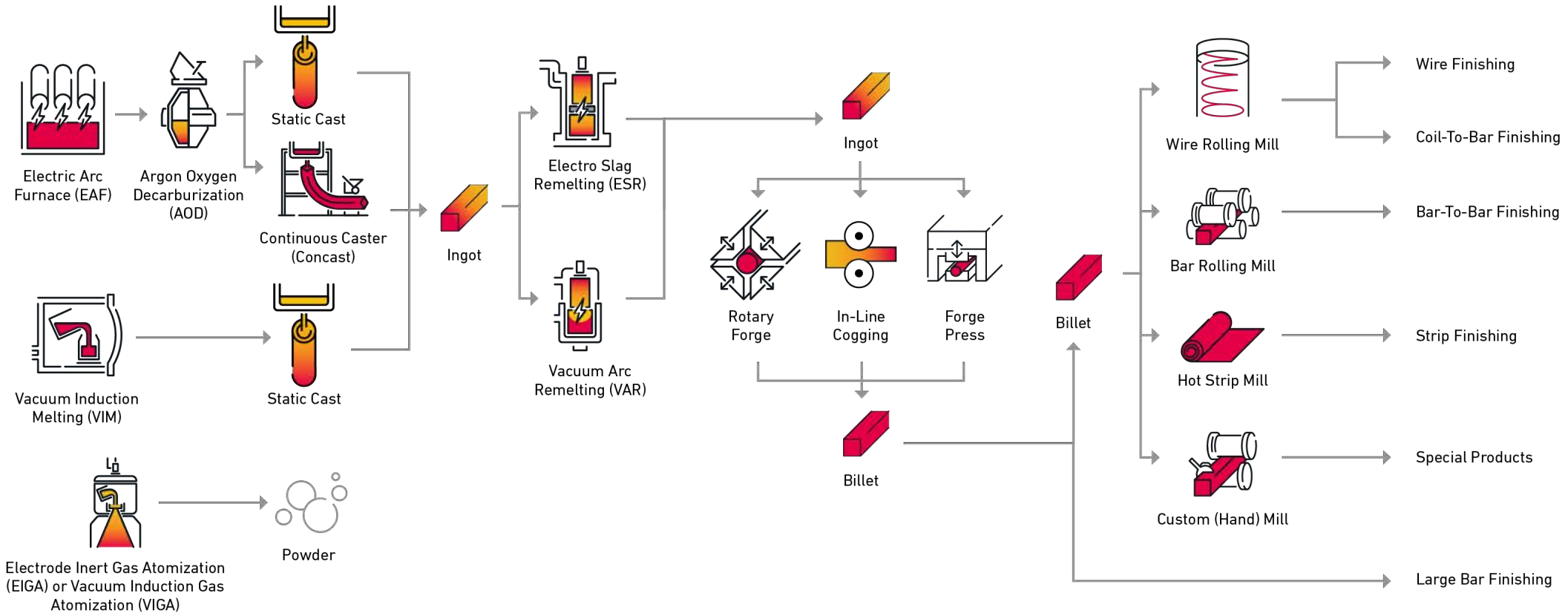
- Stainless steels
- Nickel-based
- Tool and die steels
- Cobalt-based
- Titanium-based
- Super alloys
- Alloy steels

Targeted alloy properties

- Strength
- Toughness
- High-temperature performance
- Cryogenic performance
- Wear
- Fatigue
- Corrosion resistance
- Cost

500+ high-performance alloy grades
and custom compositions available

Agile, integrated, in-house production

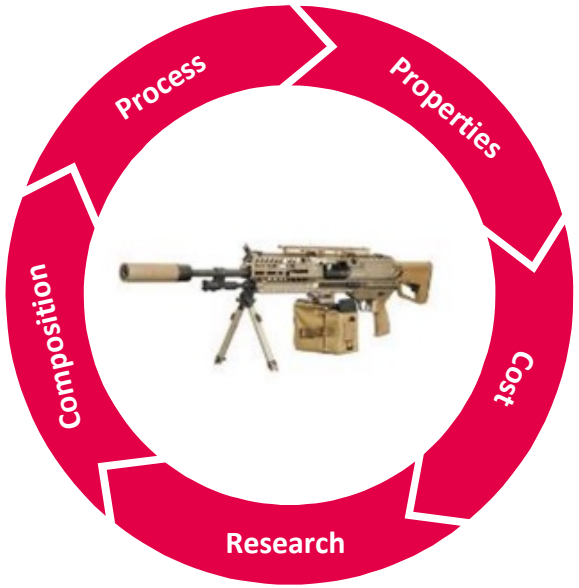


The last step is rigorous quality testing to ensure spec conformance and certification.

COLLABORATION CASE STUDY

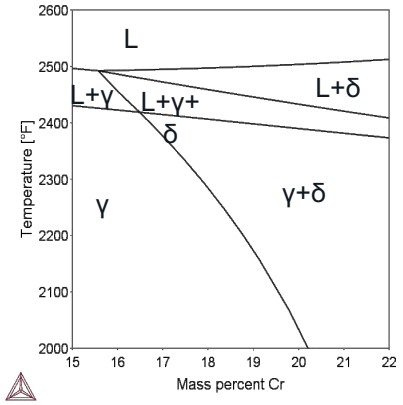
Alloy design and modeling can deliver innovative alloys in 24 months

Optimization

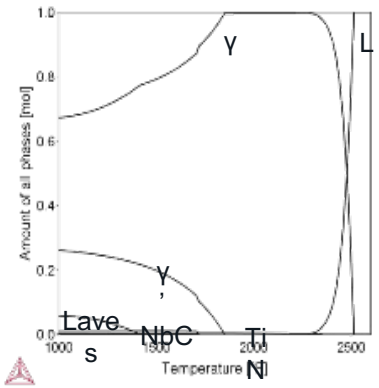


CALPHAD modeling

Thermo-Calc, Pandat, MatCalc, JMatPro



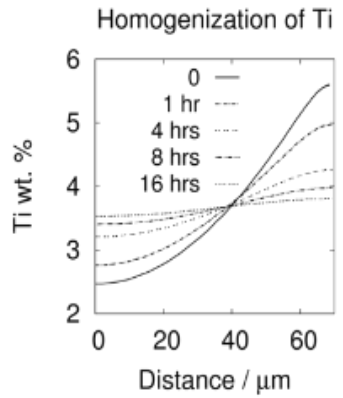
Phase composition



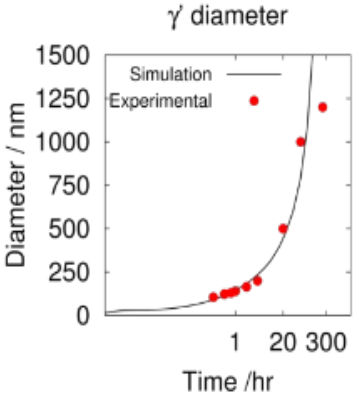
Phase stability

Kinetic modeling

Dictra, Prisma, Pandat, MatCalc



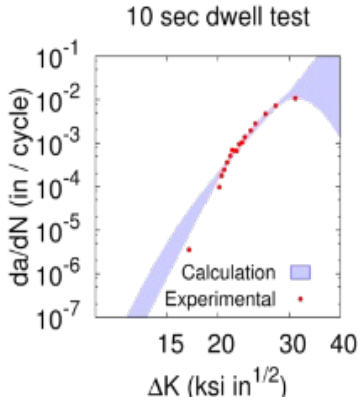
Homogenization



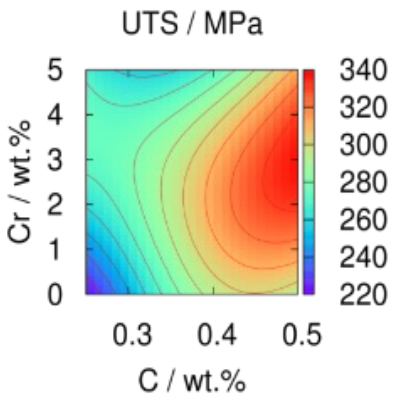
Precipitation

Data mining, empirical modeling

Neural network, Gaussian processes



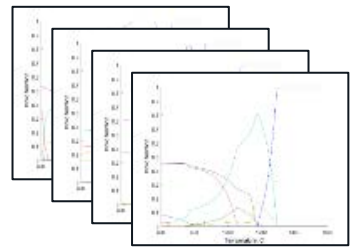
Fatigue/dwell resistance



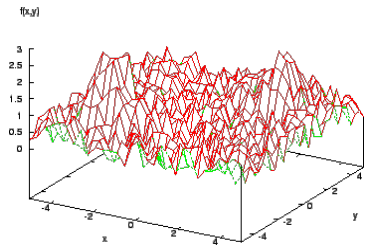
Tensile strength

Optimization

Chemistry design, property optimization, microstructure screening



High-throughput calculation



Genetic algorithm

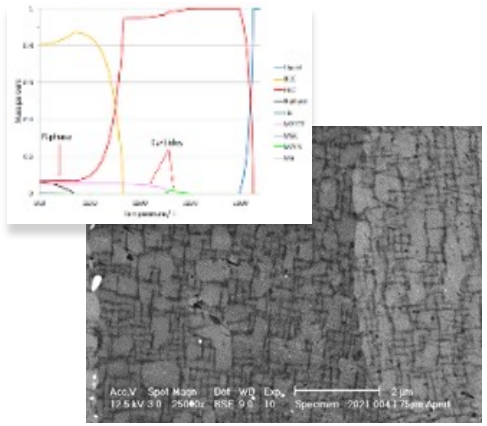
Assets and capabilities supporting new product development

Each step requires significant engineering and innovation

ALLOY DESIGN & PROTOTYPING | SMALL-SCALE PRODUCT GENERATION | TEST AND SCALE UP

Primary R&D

Determine composition, processing route, and prove lab feasibility



- Computational modeling
- Small-scale production up to 40 lbs.
- Characterization

Primary melt & remelt

Meet target chemistry, remelt for high quality ingots, achieve cleanliness targets

- Vacuum melting (400lb)
- ESR/VAR
- Powder atomization

Hot working & finishing

Achieve target structure

- Forging
- Hot/cold rolling
- Heat treating and HIP

New product development

Accomplish target properties at final form

- Forging and rolling
- Finishing
- Additive manufacturing


FORGED IN FIRE
Engineered for victory
Defense contractors depend on Carpenter Technology for never-fail alloys — high-performance, battle-proven metal.
WE HAVE YOUR BACK

HIGHER STRENGTH AND TOUGHNESS

AerMet®

Ultra-high strength / high-toughness steel

- **Best combination of strength and toughness**
- **Weight savings**
- **Endurance**
- **Damage tolerance**
- **AerMet 100 Plus**

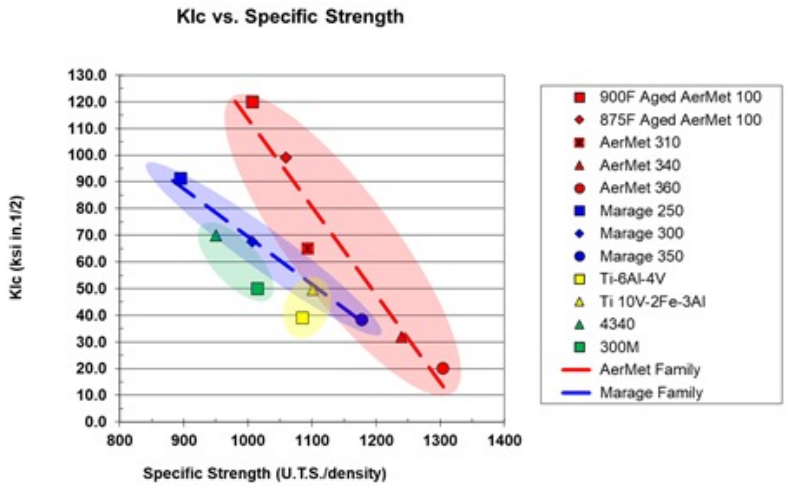
Key features

- Best combination of strength and toughness
- Formable
- Weldable
- AerMet 100 Plus for rotating components

Characteristics

- VIM/VAR for clean microstructure
- Ductile Fe-Ni-Co lath martensite matrix precipitation hardened with M_2C (M=Cr, Mo) carbides
- AerMet 100: Equal strength to 300M with double the toughness
- AerMet family provides design options based on required strength and toughness

Longitudinal Properties	AerMet 100	AerMet 310	AerMet 340	AerMet 360
Ultimate Tensile Strength (ksi)	285	315	345	365
0.2% Offset Yield Strength (ksi)	250	275	300	325
EL/RA (%)	14/65	14.5/63	11/53	6/18
Plane Strain K_{IC} (ksi √in)	115	65	34	20
Charpy V-Notch Impact Toughness (ft-lbs @RT)	30	20	11	4



Ferrium® M54

Ultra-high strength / high-toughness steel

- **Increased power density**
- **Weight savings**
- **Improved fatigue resistance and stress corrosion cracking over 300m**

Key features

- Upgrade relative to 4340, 300M, HyTuf, and maraging C250/C300
- Lower cobalt content than AerMet
- Good resistance to stress corrosion cracking

Characteristics

- Ultra-high strength steel with high toughness
- VIM-VAR premium melted
- AMS 6516 (MMPDS)
- Approvals at various OEMs

Alloy	Temper	C	Si	Mn	Cr	Ni	Co	Mo	V	Other	UTS	YS	K_{IC}
	°F (°C)										ksi	ksi	ksi √in
4340	246	0.40	0.30	0.75	0.80	1.80		0.25			264	222	50
300M	302	0.42	1.65	0.75	0.80	1.80		0.40	0.07		286	242	65
HyTuf	288	0.26	1.50	1.45	0.32	1.90		0.41			220	184	105
AerMet® 100	482	0.23			3.10	11.10	13.40	1.20			284	250	120
Ferrium® M54	523	0.30			1.00	10.00	7.00	2.00	0.10	1.3 W	293	250	110

HIGH STRENGTH AND CORROSION RESISTANCE

Custom 465®

Corrosion-resistant stainless steel

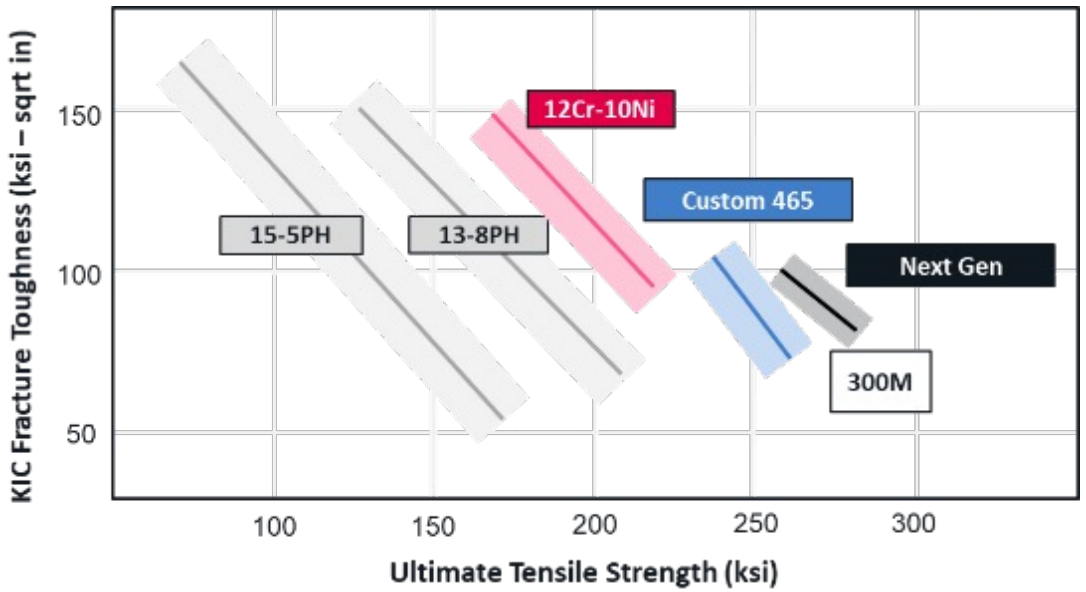
- **Improved maintenance / lifecycle costs**
- **Corrosion resistance, K_{1SCC}**
- **Weight savings**

Key features

- Higher strength relative to 15-5 PH and 13-8 PH at comparable corrosion resistance
- Comparable strength to 4330 and E35NCD16 alloy steels
- Can be cold worked to increase strength and CVN

Characteristics

- State-of-the-art high-strength PH stainless designed for aerospace applications
- Patent US5681528A (10/28/1997)
- VIM-VAR melting practice for clean microstructure
- AMS 5936, ASTM A693, ASTM A564, ASTM F899, MMPDS-11
- Approvals at most aerospace OEMs



Ferrium® S53

High-strength steel with enhanced corrosion resistance

- **Enhanced corrosion resistance relative to alloy steels, high k_{1SCC}**
- **High strength and toughness comparable to 300M**
- **Good transverse properties**

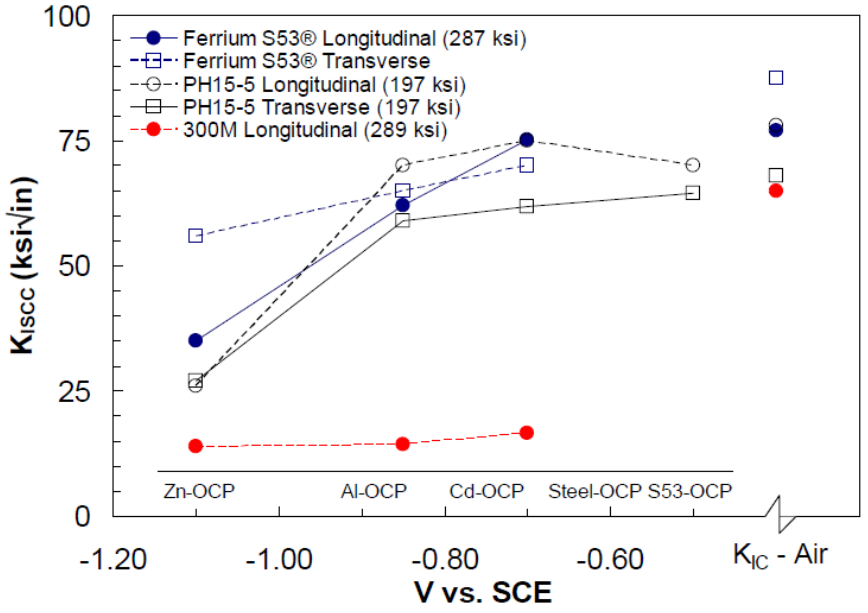
Key features

- Drop-in replacement for 300M
- CTE similar to that of other alloy steels

Characteristics

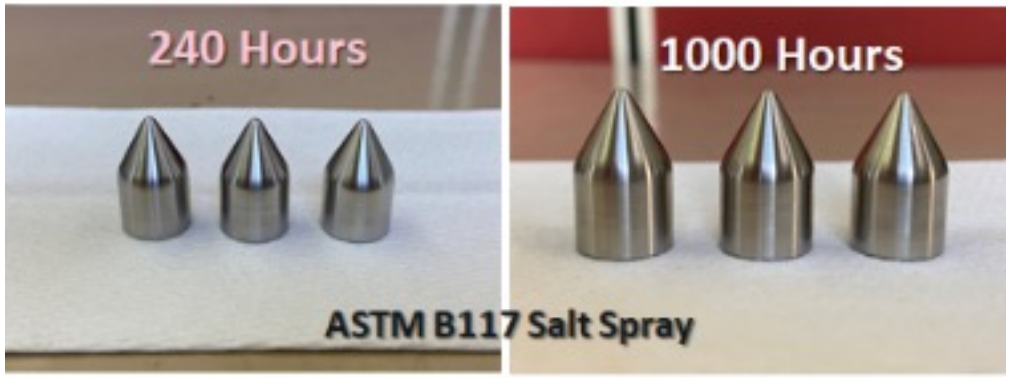
- AMS 5922, MMPDS-05
- VIM-VAR melted for clean microstructure

Mechanical Property	YS	UTS	Elongation	Reduction in Area	K_{IC}	CVN I.E.	Modulus	Density	Area Under Curve	Fatigue Stress	Toughness Index	Specific Strength
	ksi	ksi	%	%	ksi in. 1/2	ft·lbs	million psi	lbs/in³		ksi		
AerMet® 100 900 Age	246	287	16.1	67.3	120	35	28.2	0.285	4291	137	103	1007
Custom 465 H950	235	254	14	63	92	20	28.8	0.283	3423	105	72	898
Ferrium® S53	220	288	15	60	74	18	28.8	0.288	3810	120	67	1000
300M	243	287	9.8	35	50	18	29	0.283	2597	85	52	1014



Next-gen High Strength Stainless (HSS)

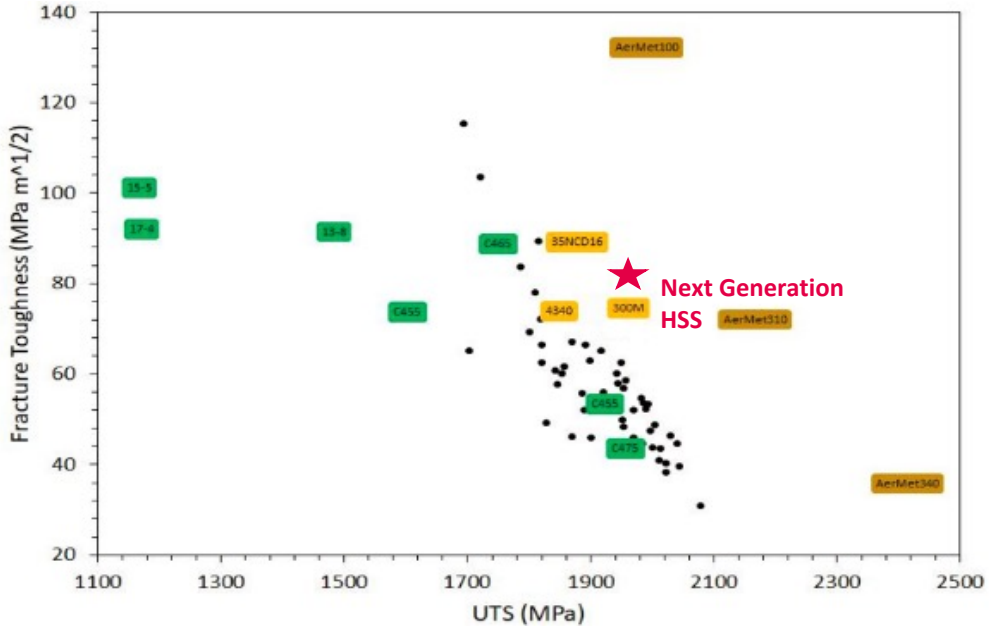
- **Elevated fracture toughness at high strength**
- **Decreased failures due to corrosion / SCC**
- **1:1 drop-in aim for 300M**
- **Decreased maintenance / lifecycle costs**



Corrosion-resistant stainless steel

Key features

- Improved strength / toughness (RT and ET) relative to Custom 465®
- Good general corrosion resistance in salt spray
- High $\frac{\sigma_{uts}}{K_{IC}}$ ratio compared to other high strength stainless steels



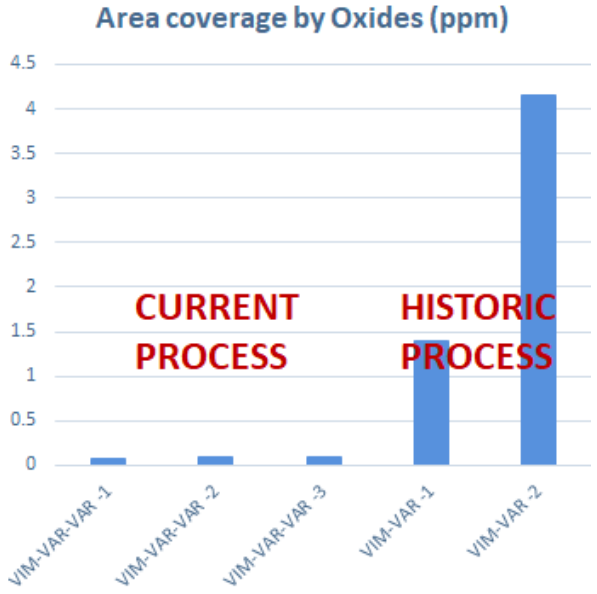
HIGHER WEAR RESISTANCE

Portfolio of carburizing alloys

Property (Long.)	VIM-VAR 9310 (AMS 6265)	Pyrowear® 53 (AMS 6308)	CBS-50 NiL (AMS 6278)	Pyrowear® 61 (AMS 6517)	Ferrium® C64 (AMS 6509)	A-21® Stainless Steel	Pyrowear® 675 (AMS 5930)	
Temper °F (°C)	300 (149)	450 (232)	1025 (552)	900 (482)	925 496)	350 (177)	600 (316)	925 496)
Case Hardness (HRC)	61	62	61	61	64	62	63	64
UTS ksi (MPa)	174 (1203)	169 (1169)	203 (1400)	239 (1650)	228 (1575)	174 (1203)	184 (1272)	
0.2%Y.S. ksi (MPa)	154 (1066)	140 (963)	174 (1200)	224 (1547)	198 (1368)	142 (979)	142 (983)	154 (1062)
K_{IC} ksi √in (MPa √m)	85 (93)	113 (125)	59 (65)	132 (145)	81 (87)	100 (110)	148 (163)	125 (138)
CVN ft-lb (J)	103 (140)	87 (118)	45 (61)	50 (68)	NA	50 (68)	NA	NA
Core Hardness (HRC)	35	35	47	50	48	41	40	39
Family	Low alloy steel	Low alloy steel	Low alloy steel	Higher alloy steel	Higher alloy steel	Stainless steel	Stainless steel	

Pyrowear® 53 (improved process)

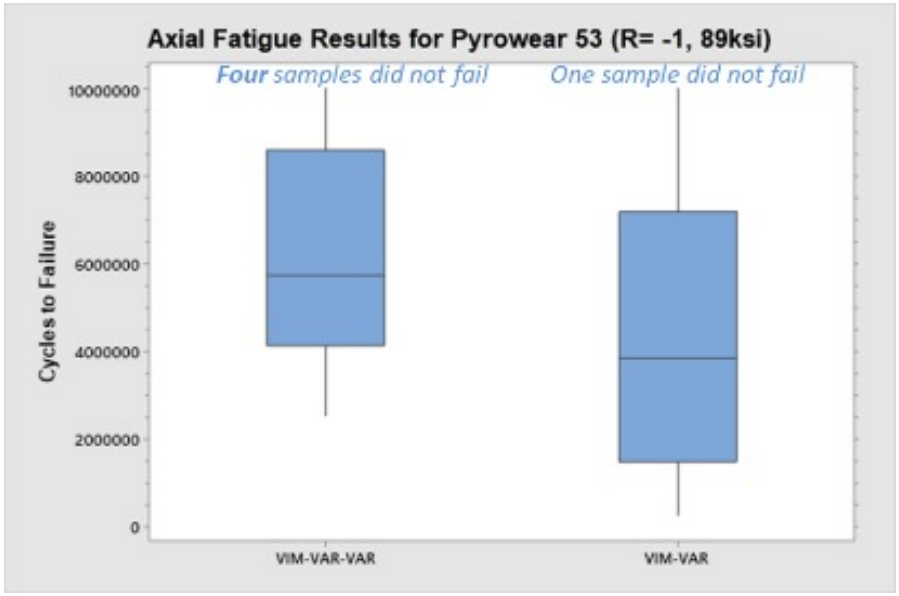
- **Increased safety, higher oil-out performance**
- **Targeted to increase fatigue life and stress ability**



High cleanliness and durability

Key features

- Reduced inclusion content
- Improved fatigue performance
- Improved ultrasonic inspection performance

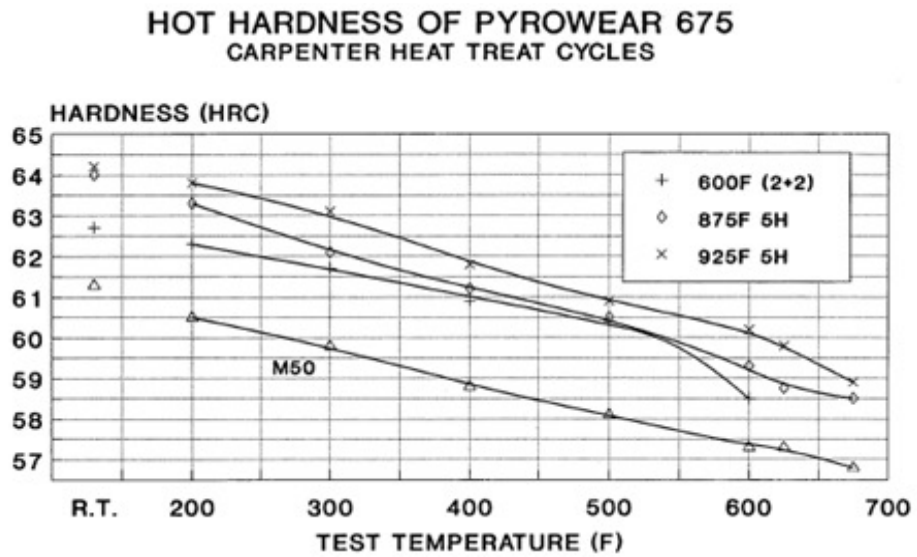


Characteristics

- Premium melted carburizing steel offering excellent wear resistance
- Exhibits a higher temper resistance compared to existing gear alloys
- Offers high case hot hardness with high core impact and fracture toughness
- Maximizes cleanliness and fatigue life

Pyrowear® 675

- **Decreased maintenance / lifecycle costs**
- **Decreased failures due to corrosion**
- **Higher engine operating temperatures (above 400°F)**



High wear resistance / corrosion resistance

Key features

- Corrosion resistance comparable to 400 series stainless steels in carburized case
- Toughness comparable to AISI 9310 in core
- Higher tempering temperatures allow for operating at higher temperatures
- Can be tempered to provide good corrosion resistance or excellent heat resistance (superior to M50), depending on desired application

Characteristics

- Carburizing corrosion-resistant gear steel designed for aerospace applications
- VIM-VAR melting practice for clean microstructure
- AMS 5930

Pyrowear® 61 and Ferrium® C64

- **Increased power density, weight savings**
- **Higher temperature resistance**
- **Leaner carburizing process (25–40% less cycle time)**

High wear resistance

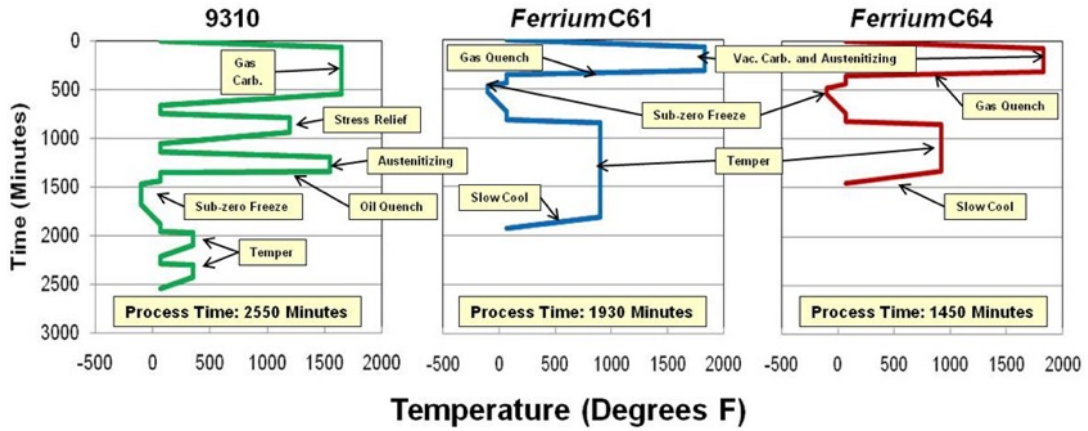
Key features

- Very high core strength / toughness
- High hardenability allows for mild gas quench that reduces distortion
- High surface hardness (61 and 64 HRC) for good wear resistance
- Increased thermal stability for improved oil-out performance
- Drop-in replacement for 9310 with increased core strength

Characteristics

- VIM-VAR melted for clean microstructure
- High core strength
- Less complex carburizing cycle
- Less distortion
- AMS 6517 and AMS 6509

Alloy	Temper	UTS	YS	HRC	K_{1c}
	°F (°C)	ksi (MPa)	ksi (MPa)	(core)	ksi √in
9310	300 (150)	174 (1200)	155 (1065)	35	85
AMS 6308 (Pyrowear® 53)	400 (204)	170 (1169)	140 (962)	35	120
Pyrowear® 61	900 (482)	239 (1650)	224 (1545)	50	115
Ferrium® C64	925 (495)	228 (1575)	199 (1370)	48	85



A-21®

- **True stainless after case hardening to >60 HRC**
- **Eliminates coating**

High wear-resistant stainless steel

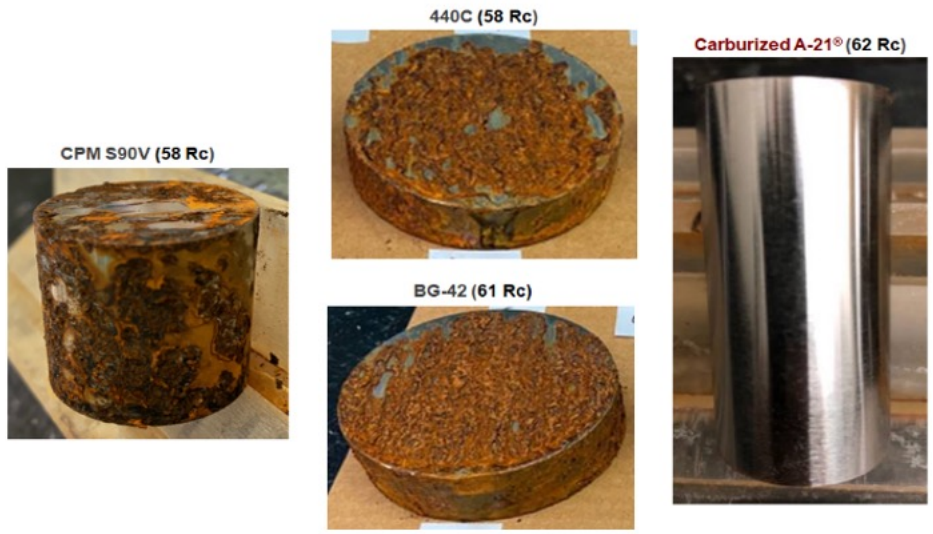
Key features

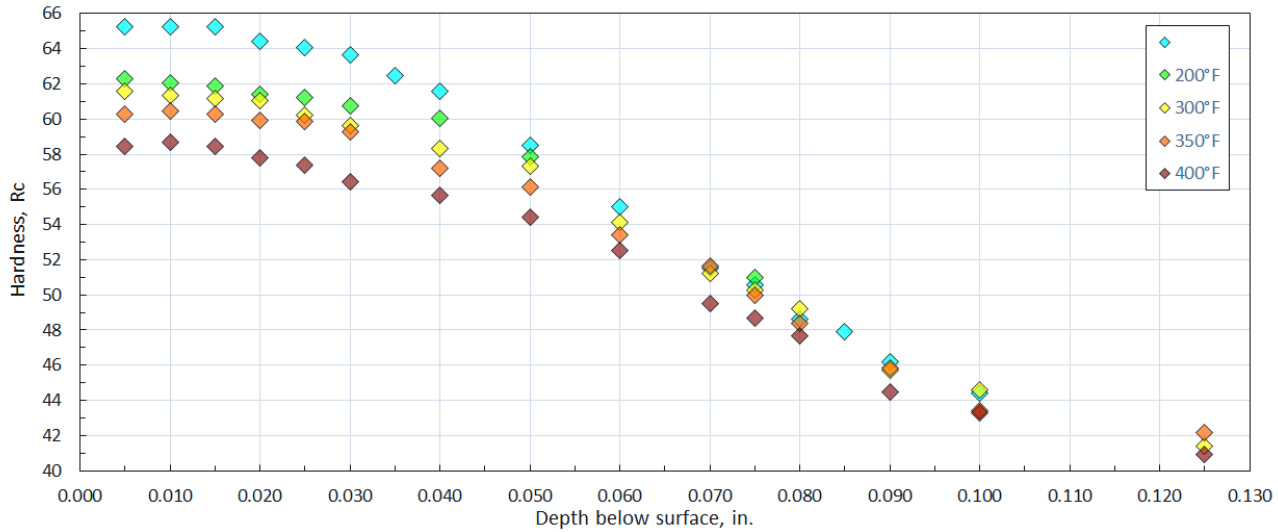
- Best-in-class corrosion resistance in carburized case
- Drop-in replacement for 9310
- Nitridable

Characteristics

- Deep, hard, stainless case + strong, tough, ductile core
- ARC/AOD, VAR or VIM-VAR
- Sizes: 0.25–10.5 in (6–267 mm) RD
- Simple process: Vacuum or gas carburize + cryo + temper

200-Hour Salt Fog Corrosion Test (ASTM B117)



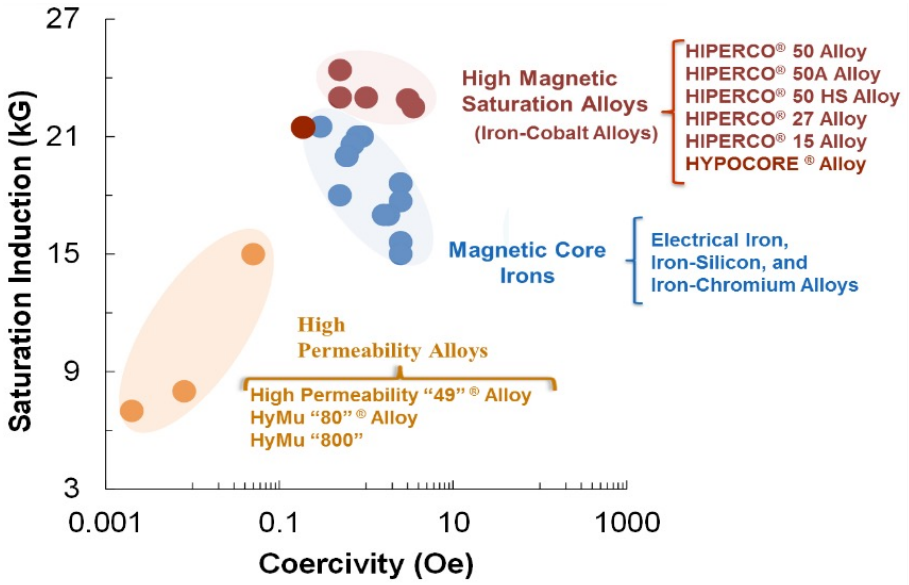


POWER-DENSE MOTORS AND GENERATORS

Advanced soft magnetic alloys

Unique combinations of mechanical properties

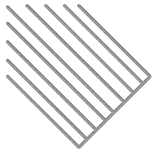
- High induction / permeability and low loss
- High strength and high induction
- High corrosion resistance and induction
- Tailored material properties, dimensions



Available in the forms you need

Alloy	Strip	Bar	Wire
Hypocore®	•		
Hiperco® 50/50A	•		
Hiperco® 27	•		
High Perm 49	•	•	•
HyMu 80	•	•	•
Chrome Core®	•	•	

Alloy	Foil Width	Foil Thickness
Hypocore®	6.4–330 mm	0.051–1.778 mm
Hiperco® 50	6.4–330 mm	0.051–1.778 mm
Hiperco® 27	6.4–330 mm	0.051–5.1 mm
High Perm 49	6.4–330 mm	0.05–6.1 mm
HyMu 80	6.4–330 mm	0.015–5.1 mm

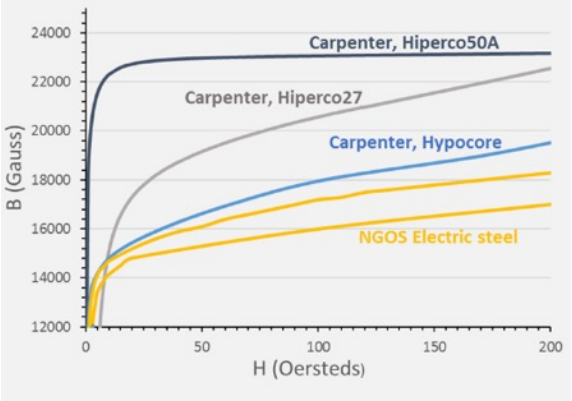

STRIP


BAR

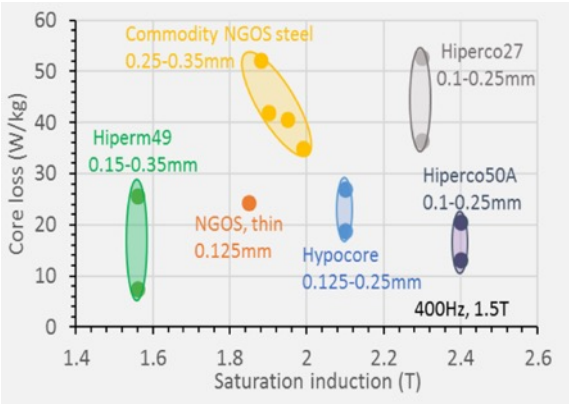

WIRE

Hiperco® has the highest induction for a soft magnetic material while exhibiting good permeability and core loss properties

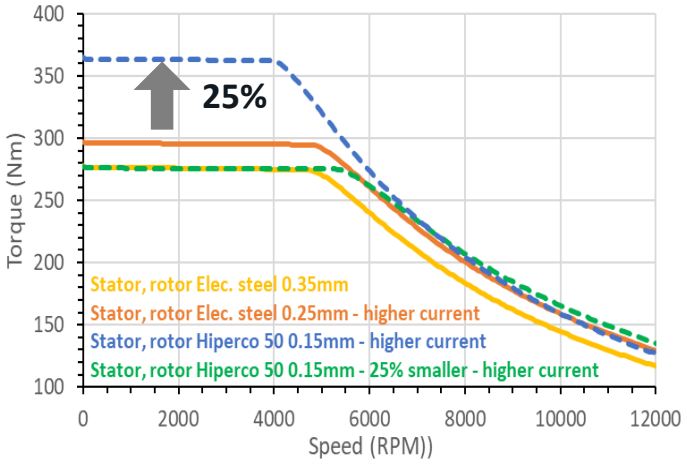
BH Curve



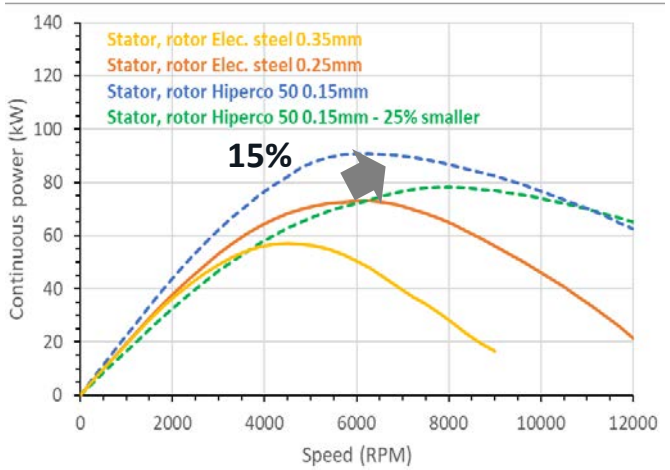
Saturation Induction vs Core Loss



Motor Torque



Motor Continuous Power



- Performance benefit may depend on specific motor design
- Simulations done for 12-pole, 72-slot, high-speed IPM machine with 0.5 mm air gap
- Design optimization, including higher power inverter, may be needed to realize enhanced responses

Hiperco® is the best choice for power-dense electric generators and motors

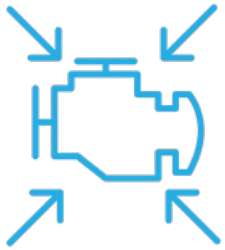
UP TO

25%

MORE

MOTOR POWER AND TORQUE

OR



UP TO

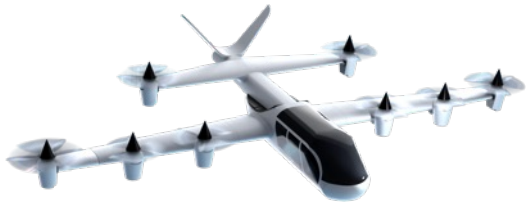
30%

SMALLER

MOTOR SIZE

Hiperco® is used in multiple high-performance applications

Advancing power, weight savings and precision



eVTOL / Urban Air Mobility

Regional Air Mobility / Electric and Hydrogen Airplanes

Legacy Aerospace and Defense

Medical Devices

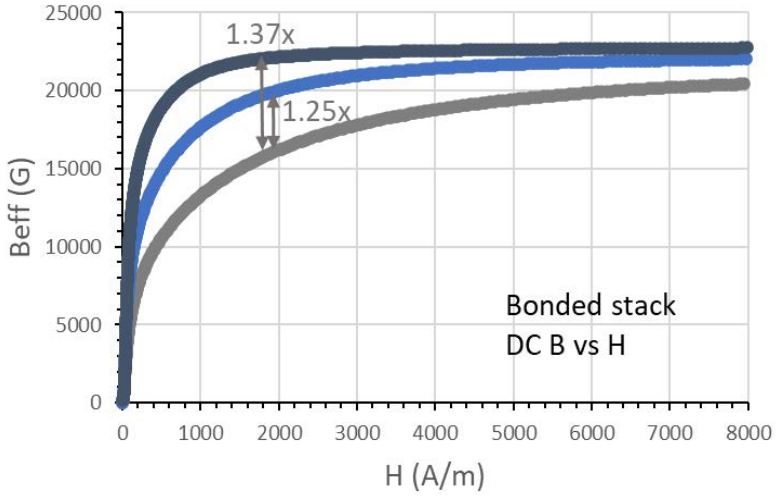
Semiconductor Production Equipment

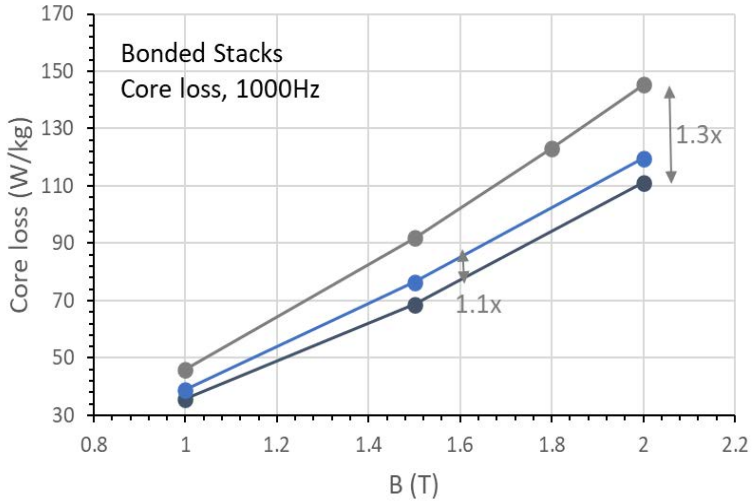
Supercars and Motor Sport

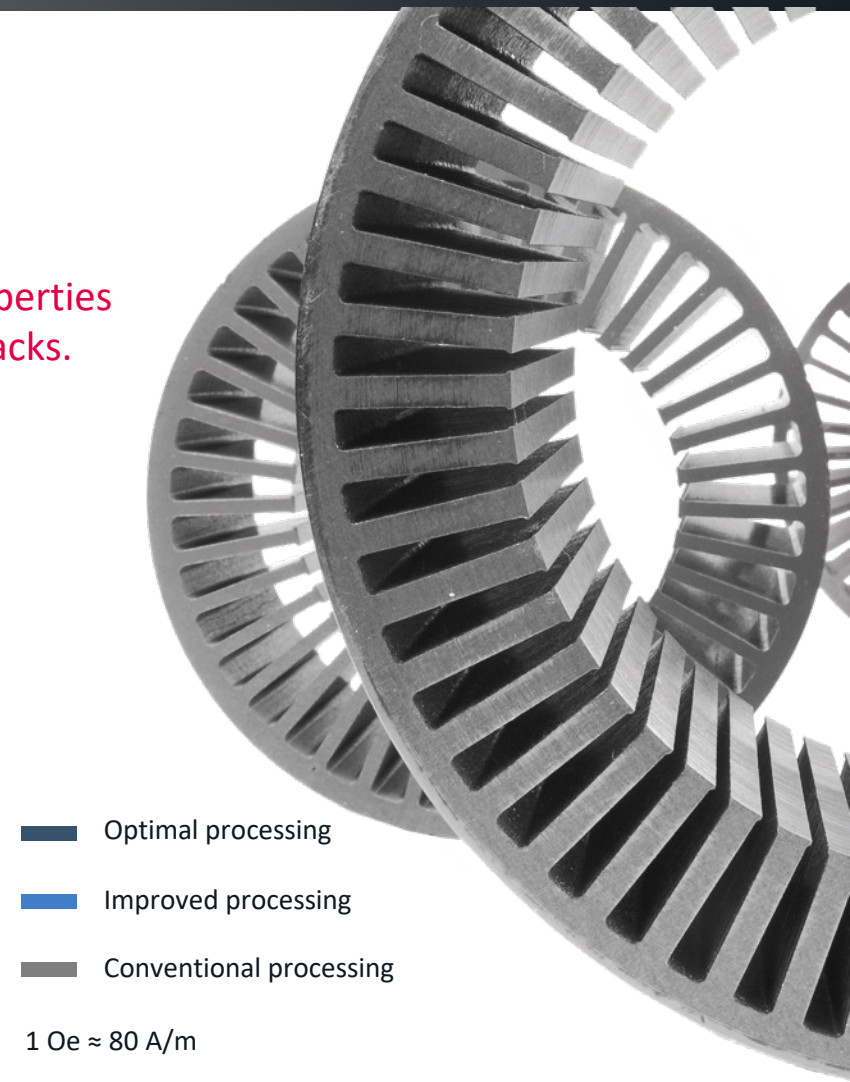
Delivering industry-best quality stacks at production scale

Power-dense stack performance is highly dependent on processing methods. Material properties and processing techniques impact the magnetic properties of Hiperco® stator and rotor stacks.

- Alloy quality (chemistry, strip process)
- Cutting process
- Growth
- Heat treatment
- Insulation
- Stress management







Optimal processing

Improved processing

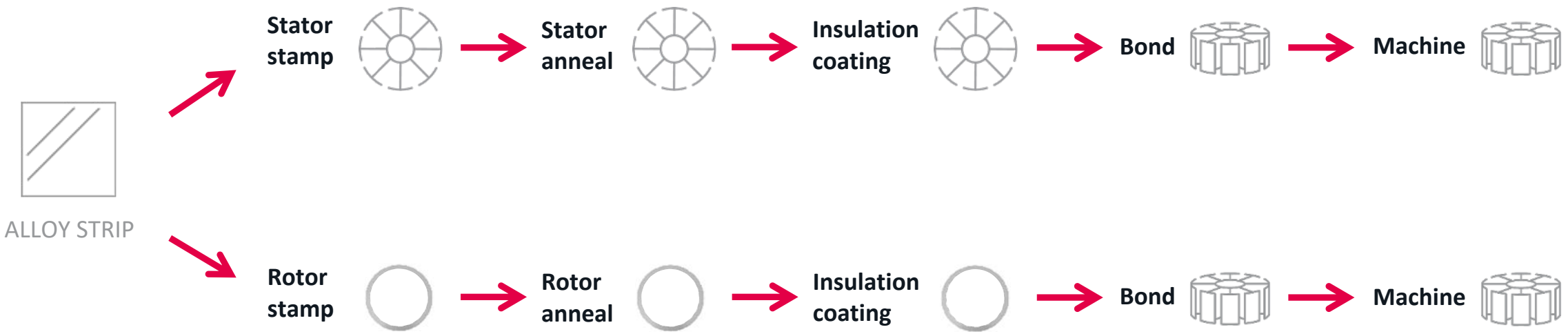
Conventional processing

1 Oe ≈ 80 A/m

Optimal processing of iron-cobalt alloys nets significant improvement in finished stack magnetic properties.

Stator and rotor parts can be produced from the same strip

Carpenter Technology follows proprietary recipes for each process step to meet customer drawing specifications

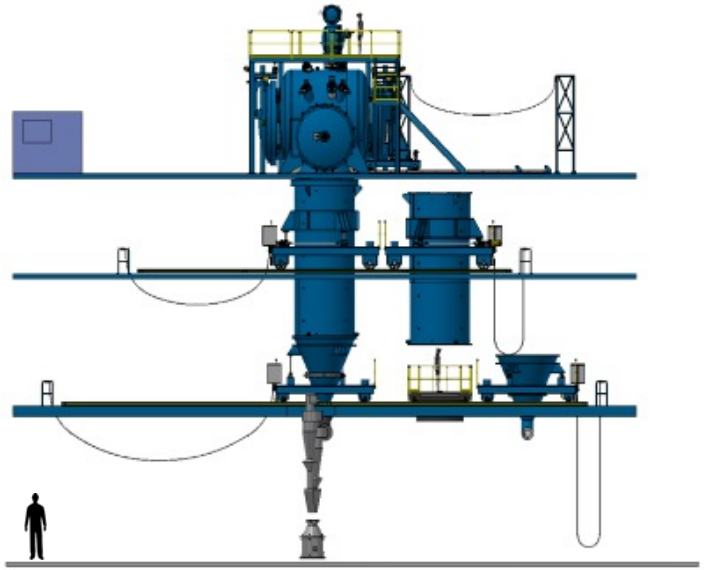


- Anneal process conditions are chosen based on magnetic and yield strength requirements
- Insulation coating process conditions are chosen based on required surface resistivity

METAL POWDER SOLUTIONS

Alloy powder manufacturing

- **VIM atomizer designed for high-temp alloys**
- **Large heat size (3000-lb VIM)**
- **Powder canning and HIP operation**



FOD control

Characteristics

- Four-story atomizer allows spherical particles after solidification
- Sophisticated tilt-pour mechanism and dual tundishes
- Clean room powder handling

Premium powders optimized for additive manufacturing

High-quality, contamination-free powders for every AM application

Carpenter Additive has developed the industry's most extensive database of mechanical properties and materials information with the expertise to advance AM.

Iron-based powders

- 316L
- 15Cr-5Ni
- 17-4
- 17-4 AR
- 304
- H13
- M300
- M300 LT

Nickel- and cobalt-based powders

- 625
- 718
- GRX-810
- CCM
- CCM-MC
- GammaPrint 1100

Titanium-based powder

- Ti64

Aluminum-based powders

- AlSi10Mg
- AlSi7Mg
- Scalmalloy

More alloys available upon request — custom specifications and sizes available.

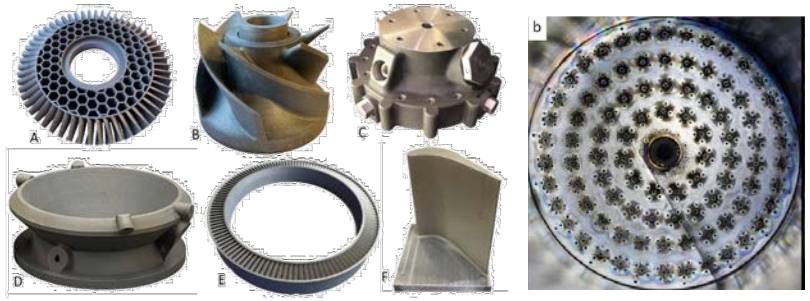
Next-gen AM material: GRX-810 ODS

Carpenter Additive has a semi-exclusive license with NASA to manufacture PowderRange® GRX-810 ODS

- **Scaled up production since Sep 2024, successfully atomized multiple full size powder heats**
- **PowderRange® GRX-810 ODS has been tested and validated by NASA GRC for both printability and mechanical performance**
- **Available in coated or uncoated powder**

Applications

Turbine and rocket components, hypersonic vehicles

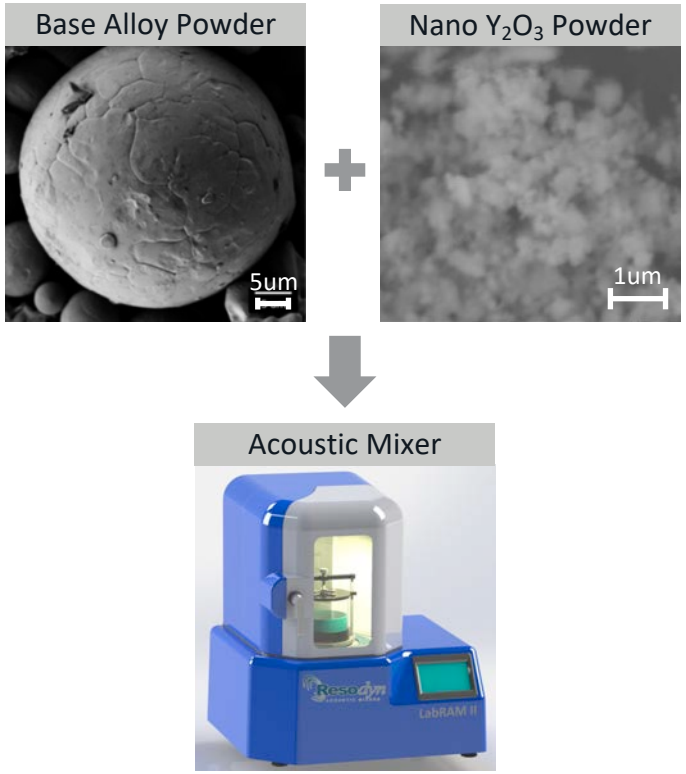


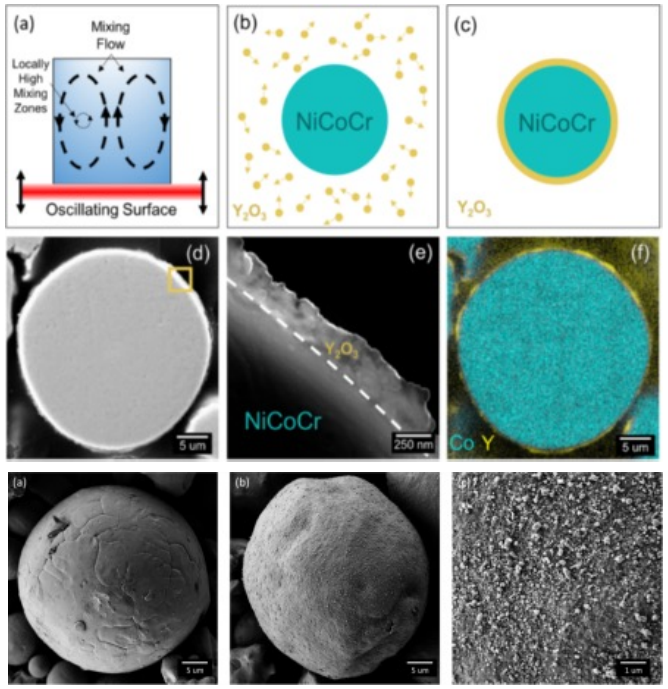
Key features

- Composition designed for additive manufacturing: crack-resistant and easy to print
- High tensile ductility (>20% elongation) across temperature range, from -195°C to 1093°C
- Outperforms 625, 718, and H230 in terms of strength at temperatures above 850°C
- High creep and stress rupture resistance up to very high temperatures — outperforms C103 at 1093°C
- High cycle fatigue performs better than 625 and H282
- Better high-temperature oxidation resistance vs. 718
- Similar thermophysical properties as 718 and 625

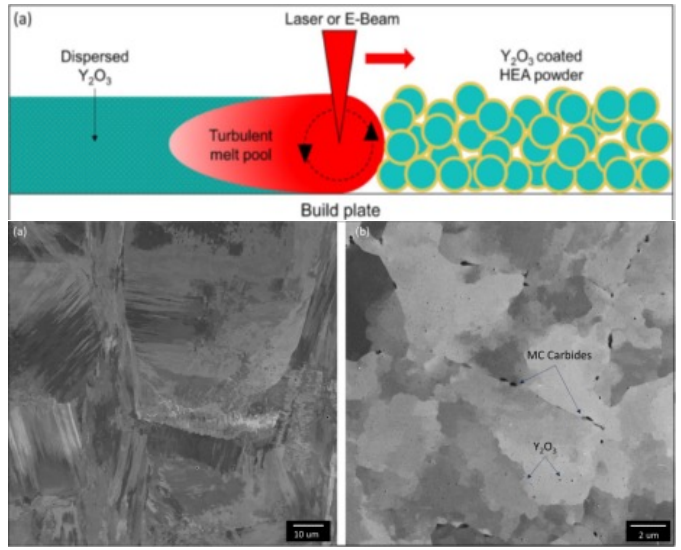
Next-gen AM material: GRX-810 ODS

Mixing alloy powder with Nano Y_2O_3





Designed for laser AM



References: 1) A 3D Printable Alloy Designed for Extreme Environments, Timothy M. Smith et al, Nature 2023. 2) NASA High Temperature Alloy Development — GRX-810, Timothy M. Smith et al, Turbo Expo Conference 2023. 3) Extreme Temperature Additively Manufactured GRX-810 Alloy Development and Hotfire Testing for Liquid Rocket Engines, 2024 AIAA SciTech, Orlando, FL.

CARPENTER TECHNOLOGY

Thank you

WE HAVE YOUR BACK

CarpenterTechnology.com/Defense

For additional information, please contact

Dan Roup | droup@cartech.com | +1 267 882 7915