PowderRange X

Applicable specifications: AMS7008

Associated specifications: UNS N06002, AMS5536, AMS5754, AMS5798, ASTM B572

Type analysis

Single figures are nominal except where noted.

Nickel	Balance	**Chromium**	20.5–23.0 %	**Iron**	17.0–20.0 %
Molybdenum	8.0–10.0 %	**Cobalt**	1.00–2.50%	**Tungsten**	0.20–1.00 %
Aluminum	0.50 %	**Copper**	0.50 %	**Manganese**	0.50 %
Silicon	0.20 %	**Titanium**	0.150 %	**Carbon**	0.10 %
Oxygen	0.10 %	**Phosphorus**	0.040 %	**Nitrogen**	0.030 %
Sulfur	0.030 %	**Boron**	0.010 %	**Hydrogen**	0.005 %

Description

PowderRange X is a solid solution strengthened nickel-chromium-iron base superalloy. It is not considered precipitation hardenable and achieves optimum material properties through solution treatments. It possesses high strength at room and elevated temperatures, and exceptional oxidation and stress corrosion cracking resistance.

PowderRange X displays significantly reduced crack susceptibility compared to the nominal alloy X composition. Its low carbon content and additional solid solution strengthening maximizes its compatibility with laser additive manufacturing processing. Although solution treatment is required for optimum high temperature performance, as-processed PowderRange X displays mechanical properties equivalent to wrought material at both room and elevated temperatures.

Key Properties:

- Exceptional strength and corrosion resistance to 2200°F (1204°C)
- Non-magnetic
- Heat and corrosion resistant

Markets:

- Aerospace
- Energy

Applications:

- Turbine rotors
- Shafts
- Buckets
- Bolts
- Afterburner components
- Furnace hardware

info@carpenteradditive.com | 610 208 2000

> PowderRange X

Powder properties

PART NUMBER	PowderRange X
APPLICATION	L-PBF[1]
MAXIMUM PARTICLE SIZE	Max 1 wt% > 53 µm[2]
MINIMUM PARTICLE SIZE	Max 10 vol% < 15 µm[3]
LSD PERCENTILE	D10, D50, D90[3], reported
ATOMIZATION	Vacuum Induction Melted, Argon Gas Atomized
APPARENT DENSITY (G/CM³)	Measured according to ASTM B212[4] and reported
HALL FLOW (S/50G)	Measured according to ASTM B213[5] and reported

[1] ASTM/ISO 52900: Laser — Powder Bed Fusion (L-PBF), Electron-Beam Powder Bed Fusion (EB-PBF), Directed Energy Deposition (DED)
[2] ASTM B214 Standard Test Method for Sieve Analysis for Metal Powders
[3] ASTM B822 Standard Test Method for Particle Size Distribution of Metal Powders and Related Compounds by Light Scattering
[4] ASTM B212 Standard Test Method for Apparent Density of Free-Flowing Metal Powders Using the Hall Flowmeter Funnel
[5] ASTM B213 Standard Test Method for Flow Rate of Metal Powders Using the Hall Flowmeter Funnel
Testing of powder will fulfill certification requirements to Nadcap Materials Testing and ISO/IEC 17025 Chemical, per relevant ASTM procedures

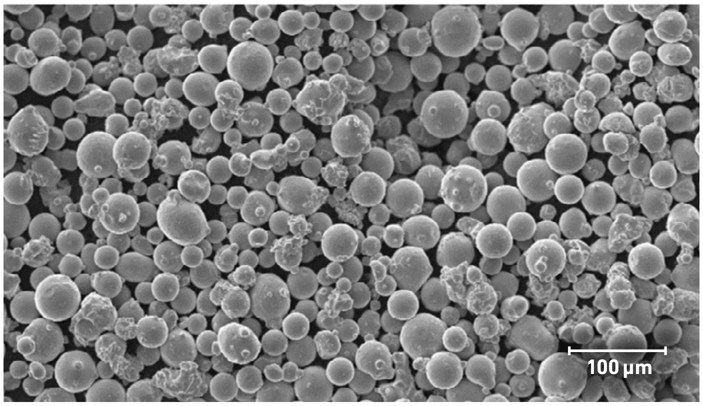


FIGURE 1 — SEM IMAGE OF TYPICAL POWDERRANGE X POWDER

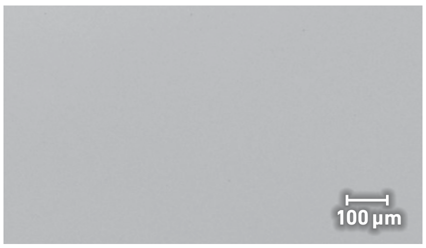
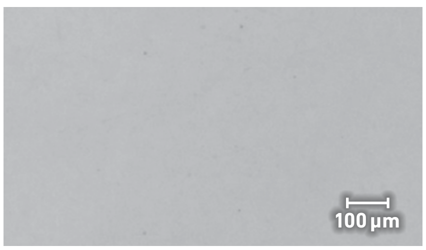
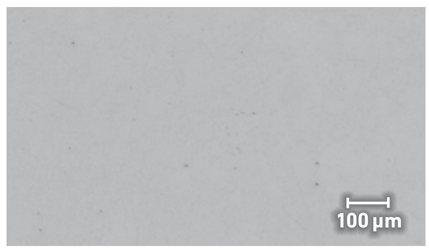
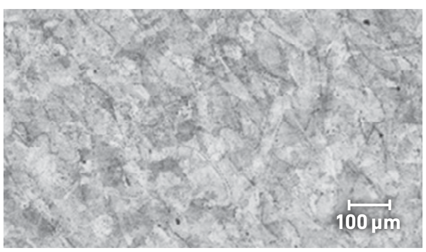
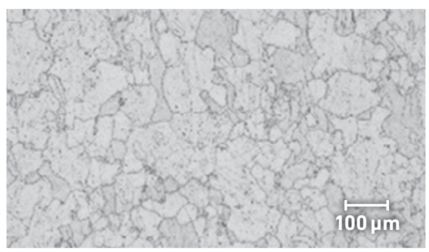
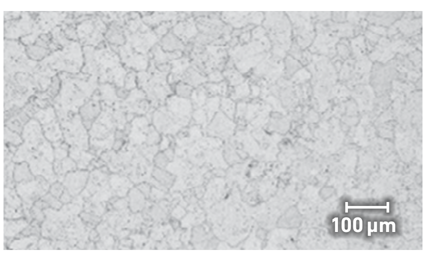
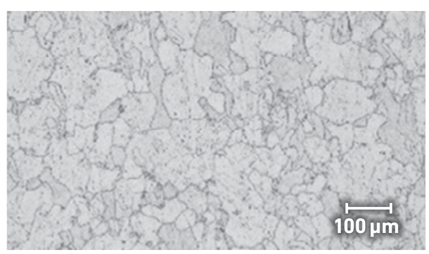
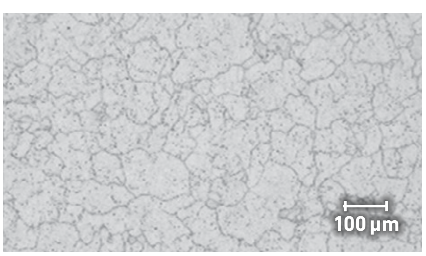
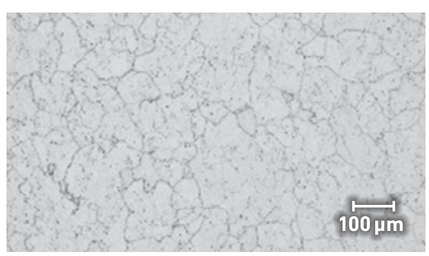
> PowderRange X

Additive manufacturing process guidance

ASTM/ISO 52900: LASER-POWDER BED FUSION (L-PBF)	
Laser-Powder Bed Fusion (L-PBF) As-built	PowderRange X is compatible with all commercially available L-PBF equipment. To achieve mean, as-built density >99.9%, 30 μm layer thicknesses and Specific Energy ≥ 59 J/mm³ is recommended.
Solution Anneal and Age (Sol/Age)	Solution Anneal at 2150°F (1177°C) for 1 hour. To provide an adequate quench after solution treating, it is necessary to cool below 1000°F (540°C) rapidly enough to prevent precipitation in the intermediate temperature range. For thin geometries, rapid air cooling suffices. For heavier sections not subject to cracking, oil or water quenching is frequently required. While generally not necessary to age, an aging treatment can be applied at 1400°F (760°C); hold 3 hours; air cool; reheat to 1100°F (595°C); hold 3 hours; cool in air. **Schedules tailored better to the AM process thermal history may be available. Please contact Carpenter Technology for information.**
Hot Isostatic Pressed condition (HIP/Sol/Age)	We recommend HIP as standard practice for microstructure homogenization; removal of residual spatter-induced voids, trapped gas porosity in powder and keyhole porosities; as well as to heal any shrinkage-induced micro-cracks in the material. **To achieve up to full density (100%):** Process components under inert atmosphere at not less than 14.5ksi (100 MPa) at approximately 2300°F (1260°C); hold at the selected temperature for approximately 240 minutes or more. Follow with Solution and Age treatment as described above.
Machinability	To machine PowderRange X, we recommend using single-point tungsten carbide tools. Increasing the speed and decreasing the feed results in better finishes. Excessive speeds are not recommended because the tools will break down. A sulfur-base cutting fluid should be used. Ample coolant is suggested. Removal of cutting fluid is necessary before heat treating because the sulfur will offset the surface of the part. A rigid work piece and a rigid tool are necessary for optimum machinability.

> PowderRange X

TYPICAL MICROSTRUCTURES

CONDITION	TRANSVERSE (X-Y PLANE)	LONGITUDINAL (Y-Z PLANE)	NOTES
As-built			Mean densities greater than 99.9%
HIP/Sol			Mean densities up to 100%
As-built, etched[6]			Clean weld tracks visible Minimal spatter porosity
Sol/Age, etched[6]			Recrystallized equiaxed grain structure minimizes anisotropy Grain size: ASTM 4.0-5.5[7]
HIP/Sol/Age, etched[6]			Recrystallized equiaxed grain structure minimizes anisotropy Grain size: ASTM 4.0-4.5[7]

[6] *Etched with oxalic+HCl*
[7] *ASTM E112-13 Standard Test Method for Determining Average Grain Size*

> PowderRange X

Typical achievable mechanical properties

ROOM TEMPERATURE MECHANICAL PROPERTIES[8]

FORM	ORIENTATION	0.2% YIELD STRENGTH $\sigma_{0.2\%}$		ULTIMATE TENSILE STRENGTH σ_{UTS}		ELONGATION IN 4D	REDUCTION OF AREA	IMPACT ENERGY		HARDNESS
		ksi	MPa	ksi	MPa	%	%	FT-LBS	J	HRB
As-built	X and Y	96	663	127	876	34	58	60	81	100
	Z	84	577	113	780	43	64	73	99	99
Sol/Age	X and Y	57	393	118	816	41	49	60	82	92
	Z	55	382	114	786	44	54	66	90	93
HIP/Sol/Age	X and Y	55	379	118	811	44	52	70	95	92
	Z	54	375	114	786	46	55	76	102	92
ASTM Spec.[9]	—	35	240	95	655	35	—	—	—	90[10]

[8] *Average of a minimum of 5 samples taken from across the extents of a build plate in each orientation and for each heat treatment. Testing performed in accordance with ASTM E8/E8M-16a (tensile), ASTM E23-18 (impact energy) and ASTM E18-19 (hardness). Additional data may be available through a wide range of consortia and other collaborations. Please contact Carpenter Additive for additional information.*

[9] *ASTM B572-06 (2016) Mechanical Property Requirements for N06002*

[10] *Carpenter Technology Alloy 680 alloy bar and plate typical values*

Corrosion resistance

IMPORTANT NOTE:
The following 4-level rating scale (Excellent, Good, Moderate, Restricted) is intended for comparative purposes only and is derived from experiences with wrought product. Additive manufactured material may perform differently; corrosion testing is recommended. Factors that affect corrosion resistance include temperature, concentration, pH, impurities, aeration, velocity, crevices, deposits, metallurgical condition, stress, surface finish, and dissimilar metal contact.

Nitric Acid	Good	**Sulfuric Acid**	Good
Phosphoric Acid	Good	**Acetic Acid**	Excellent
Sodium Hydroxide	Good	**Salt Spray (NaCl)**	Excellent
Sea Water	Excellent	**Sour Oil/Gas**	Good
Humidity	Excellent		

> POWDERRANGE X

Similar materials

COMPANY	ALTERNATIVE TITLE
Other Generic Names	Hast X, Alloy X
3D Systems	—
GE (Concept Laser)	—
EOS	NickelAlloy HX
DMG Mori (Realizer)	—
Renishaw	—
SLM Solutions	HX

info@carpenteradditive.com | 610 208 2000

For additional information, please contact your nearest sales office:
info@carpenteradditive.com | 610 208 2000

The mechanical and physical properties of any additively-manufactured material are strongly dependent on the processing conditions used to produce the final part. Significantly differing properties can be obtained by utilizing different equipment, different process parameters, different build rates and different geometries. The properties listed are intended as a guide only and should not be used as design data.

The information and data presented herein are typical or average values and are not a guarantee of maximum or minimum values. Applications specifically suggested for material described herein are made solely for the purpose of illustration to enable the reader to make his/her own evaluation and are not intended as warranties, either express or implied, of fitness for these or other purposes. There is no representation that the recipient of this literature will receive updated editions as they become available.