Meltio Stainless Steel 316L

ER316LSI / G 19 12 3 L Si / 1.4430

SS316L is an austenitic steel with excellent durability, low reactivity and adequate elevated temperature properties. The alloy has a low carbon content which makes it particularly recommended when there is a risk of intergranular corrosion. Thus, parts manufactured with SS316L are an excellent choice in corrosion prone applications.

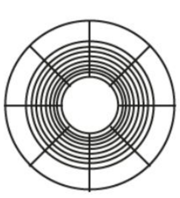
Properties	Corrosion Resistance, Machinable and Polishable
Applications	Machinery, Chemical and Food Industry and Naval

Wire Chemical Composition	Fe	C	Si	Mn	Cr	Ni	Mo
Weight Percent [%]	Bal.	0.02	0.9	1.7	18.5	12.0	2.7

Wire Density
8.0 g/cm³

Melting Point		
1671 K	1398 ºC	2548 °F

Spool Specs



Meltio Materials are tightly spooled and packaged to ensure the best compatibility with Meltio systems.

Wire Diameter	1.0 mm
Weight on Spool	15 kg
Volume on Spool	1875 cm³
Spool Type	BS300
Wire Coating	Uncoated

Heat Treatment

With SS316L it is not mandatory to perform a heat-treatment after 3D printing for general use case applications. As-built Meltio SS316L parts show a mainly austenitic structure with some ferrite content. This Ferrite content may be adjusted via re-austenization to fit the requirements of a specific application. Applying the heat-treatment a 99.8% austenitic structure structure can be achieved. SS316L may also be stress relieved between 450°C and 600°C without affecting its microstructure.

Re-austenization*

Protective atmosphere	1050°C	Maintain for 2h	Cooling at 20°C/s to RT

**Typical Parameters for a cylinder sample of 4 mm diameter and 10 mm long.*

Deposition Parameters

The following 3D printing parameters were found to provide fully dense samples. Please use the provided “Density Profiles” and refer to the document “Printing Parameters and their effect on part density” for additional information.

Laser Power [W]	Velocity [mm/s]	Argon Flow [l/min]	Layer Height [mm]	Wire Speed [mm/s]	Energy Density [J/mm3]
1100	7.5	10	1.0	9.6	147

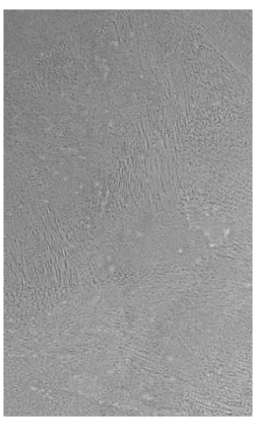
Meltio Material Datasheet

Meltio Stainless Steel 316L

ER316LSI / G 19 12 3 L Si / 1.4430

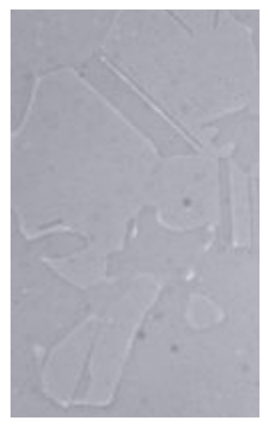
Micrography

The as-built SS316L samples show a microstructure with both cellular and columnar dendritic solidification mode. In as printed condition we find 5.6% ferritic structures which are reduced to 0.2 % after heat-treatment at 1050 ºC.



As-printed XY
100x Magnification

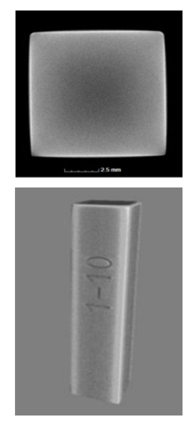
As-printed XY
1000x Magnification



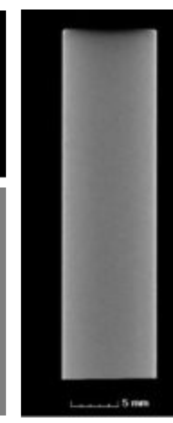
HT1050 XY
100x Magnification

Tomography

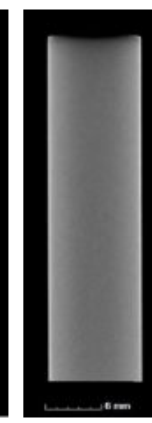
Computed Tomography Scan of 3D printed sample part in SS316L without detectable voids or defects. Resolution of 24 µm per pixel.



3D / Top View



Left View



Front View

Relative density as 3D printed	99.96%

Mechanical Properties

Results show that specimens printed using Meltio's wire-laser metal 3D printed process perform at the same level as samples made with conventional manufacturing methods. Results show low deviations and near isotropic properties even in the as printed state without the application of heat-treatments.

			UNE EN ISO 6892-1			
	Cast Properties (ASTM A403)	**Wrought Properties (ASTM A351)**	**Meltio XY properties (As printed)**	**Meltio XY properties (H.T)**	**Meltio XZ properties (As printed)**	**Meltio XZ properties (H.T)**
Ultimate Tensile strength (UTS) [MPa]	515	550	643 ± 16	547 ± 8	655 ± 28	556 ± 8
Yield strength [MPa]	208	260	429 ± 6	253 ± 17	347 ± 11	215 ± 3
Elongation [%]	40	35	38 ± 2	62 ± 2	41 ± 4	65 ± 1
			**Test Carried Out In IDONIAL* i+d+i@cetemet.es			

			UNE EN ISO 6507-1	
	Cast Properties *(ASTM A403)*	**Wrought Properties *(ASTM A351)***	**Meltio Properties *(As printed)***	**Meltio Properties *(H.T)***
Hardness [HV-30]	215	225	198	192
			**Test Carried Out In IDONIAL* info@strainanalysisuja.es	

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Meltio Stainless Steel 17-4PH

17-4PH / ER 630 / 1.4542 / UNS S17400

17-4PH is a precipitation-hardening martensitic stainless steel with excellent mechanical properties and corrosion resistance. It is a versatile material with high strength, good toughness, and good resistance to stress corrosion cracking, making it ideal for a wide range of applications in the aerospace and chemical industries.

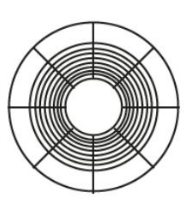
Properties	High Strength, Low Weight, Corrosion Resistance and Heat Treatable
Applications	Aerospace, Chemical Industries, Oil & Gas, Defense and Naval

Wire Chemical Composition	Fe	C	Ni	Si	Mn	Cr	Mo	Nb	Cu
Weight Percent [%]	Bal.	0.02	4.7	0.4	0.5	16.5	0.2	0.23	3.4

Wire Density
7.75 g/cm³

Melting Point		
1677 - 1713 K	1404 - 1440 ºC	2559 - 2624°F

Spool Specs



Meltio Materials are tightly spooled and packaged to ensure the best compatibility with Meltio systems.

Wire Diameter	1.0 mm
Weight on Spool	15 kg
Volume on Spool	1935 cm³
Spool Type	BS300
Wire Coating	Uncoated

Heat Treatment

To achieve the best mechanical properties, 17-4PH should be heat-treated after 3D printing. The standard heat treatment process for 17-4PH involves two steps: Solution Annealing and Age Hardening. Solution annealing removes internal stresses of the metal that have been formed during 3D printing and Age Hardening will upgrade the mechanical properties. Machining may take place before or after the solution annealing depending on part tolerance requirements.

Solution Annealing

HT.1: [Condition A]	1030ºC-1050ºC Hold 1 hour Slow cooling

Age Hardening

HT.2: [H900]	480ºC-490ºC Hold 1 hour Slow Cooling to RT

**Typical Parameters for a Sample of 160x60x30 mm*

Deposition Parameters

The following 3D printing parameters were found to provide dense samples. Please use the provided “Density Profiles” and refer to the document “Printing Parameters and their effect on part density” for additional information.

Laser Power [W]	Velocity [mm/s]	Argon Flow [l/min]	Layer Height [mm]	Wire Speed [mm/s]	Energy Density [J/mm3]
1100	7.5	10	1.0	9.6	147

MELTIO

Meltio Material Datasheet

Meltio Stainless Steel 17-4PH

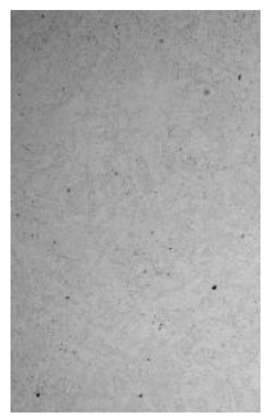
17-4PH / ER 630 / 1.4542 / UNS S17400

Micrography

The as printed microstructure of 17-4 PH stainless steel is heterogeneous and mostly martensitic with some retained austenite.
Solution Annealing and Age Hardening results in a significantly refined grain structure with a predominantly martensitic microstructure and equiaxed morphology.

As-printed XZ
100x Magnification

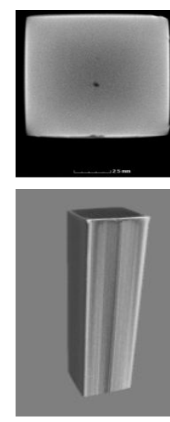
As-printed XZ
1000x Magnification



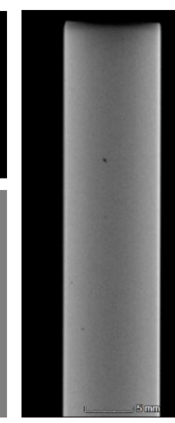
HT.1+ HT.2
1000x Magnification

Tomography

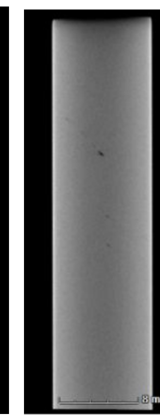
Computed Tomography Scan of 3D printed sample part in 17-4PH showing small detectable voids. Resolution of 24 µm per pixel.



3D / Top View



Left View



Front View

Relative density as 3D printed	99.90%

Mechanical Properties

Results show that specimens printed using Meltio's wire-laser metal 3D printed process perform at the same level as samples made with conventional manufacturing methods. Testing is carried out in the less favorable XZ direction to ensure the values are applicable across complete part.

		UNE EN ISO 6892-1	
	Wrought Properties (ASTM 1472)	**Meltio XZ Properties (HT.1 + HT.2)**	**Meltio XZ Properties (As Printed)**
Ultimate Tensile strength (UTS) [MPa]	1310	1391 ± 7	1017 ± 15
Yield strength [MPa]	1170	1243 ± 8	815 ± 17
Elongation [%]	10	10 ± 3	14 ± 0.1
		**Tests Carried Out In IDONIAL info@idonial.com*	

		UNE EN ISO 6507-1	
	Wrought Properties (ASTM 1472)	**Meltio Properties (HT.1 + HT.2)**	**Meltio Properties (As Printed)**
Hardness [HV-30]	388	393	258
		**Tests Carried Out In IDONIAL info@idonial.com*	

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Meltio Mild Steel ER70-S

ER70S-6 / S 42 4 M21 3Si1 / AWS A5.18

ER70-S, also known as low alloy carbon steel or mild steel, is a highly versatile material due to its strength, ductility, and low cost. It is used in many applications, including construction, automotive and manufacturing. Its excellent weldability and machinability make it easy to work with, while its high ductility and toughness make it suitable for structural applications.

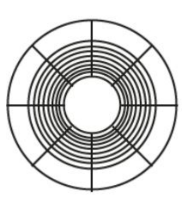
Properties	Low Cost, Easily Machined, Highly Ductile and Magnetic
Applications	Manufacturing, Tools and prototypes and Automotive industries

Wire Chemical Composition	Fe	C	Mn	Si	S	P
Weight Percent [%]	Bal.	0.07	1.45	0.85	0.02	0.01

Wire Density
7.8 g/cm³

Melting Point		
1700 - 1760 K	1425 - 1485ºC	2600 - 2700°F

Spool Specs



Meltio Materials are tightly spooled and packaged to ensure the best compatibility with Meltio systems.

Wire Diameter	1.0 mm
Weight on Spool	15 kg
Volume on Spool	1923 cm³
Spool Type	BS300
Wire Coating	Uncoated

Heat Treatment

With ER70-S it is not mandatory to perform a heat-treatment after 3D printing for general use case applications. A Normalizing heat treatment can be applied to ER70-S to improve its microstructure and mechanical properties. By eliminating unstable constituents such as acicular ferrite and bainite, a more uniform and homogeneous microstructure is achieved, leading to a better distribution of pearlite and ferrite. This results in increased ductility and toughness, as well as a reduction in the anisotropy of the material.

Normalization*

Nitrogen atmosphere Heat up to 900°C	Maintain for 2h Cooling in air to RT

**Typical Parameters for a Sample of 160x60x30 mm*

Deposition Parameters

The following 3D printing parameters were found to provide fully dense samples. Please use the provided “Density Profiles” and refer to the document “Printing Parameters and their effect on part density” for additional information.

Laser Power [W]	Velocity [mm/s]	Argon Flow [l/min]	Layer Height [mm]	Wire Speed [mm/s]	Energy Density [J/mm3]
1100	7.5	10	1.0	9.6	147

Meltio Material Datasheet

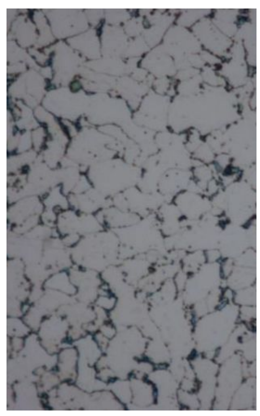
Meltio Mild Steel ER70-S

ER70S-6 / S 42 4 M21 3Si1 / AWS A5.18

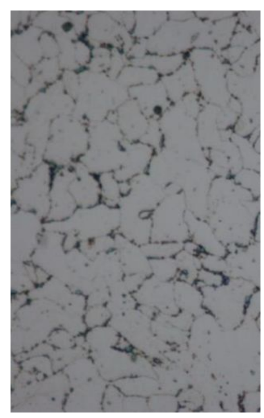
Micrography

The investigation reveals that the microstructure of the ER70-S specimens consists of a ferritic matrix intermixed with pearlite at the grain boundaries, wherein the interlayers exhibit larger grain sizes owing to the heat generated during material deposition.

As-printed XY
100x Magnification



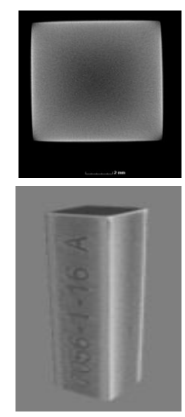
As-printed XY
1000x Magnification



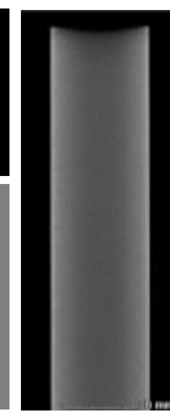
As-printed XZ
1000x Magnification

Tomography

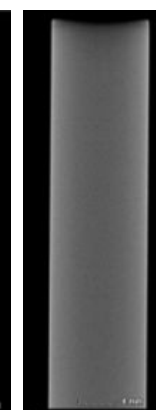
Computed Tomography Scan of 3D printed sample part in ER70-S without detectable voids or defects. Resolution of 24 µm per pixel.



3D / Top View



Left View



Front View

Relative density as 3D printed	99.19%

Mechanical Properties

Results show that specimens printed using Meltio's wire-laser metal 3D printed process perform at the same level as samples made with conventional manufacturing methods. Results show low deviations and near isotropic properties in the as printed state without the application of heat-treatments.

			UNE EN ISO 6892-1	
	Cast Properties (ASTM A352)	**Wrought Properties (ASTM A36)**	**Meltio XY Properties (As printed)**	**Meltio XZ Properties (As printed)**
Ultimate Tensile strength (UTS) [MPa]	415 - 585	400 - 550	598 ± 5	525 ± 12
Yield strength [MPa]	205	250	484 ± 8	402 ± 37
Elongation [%]	24	23	71 ± 1	15 ± 9
			**Tests Carried Out in CETEMET i+d+i@cetemet.es*	

			UNE EN ISO 6507-1
	Cast Properties (ASTM A352)	**Wrought Properties (ASTM A36)**	**Meltio Properties (As printed)**
Hardness [HV-30]	160	127	175
			**Test Carried Out In the University of Jaen (UJA) info@strainanalysisuja.es*

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Meltio Nickel 718

ERNiFeCr-2 / S Ni 7718 / 2.4667

Nickel 718 is a highly versatile and corrosion-resistant alloy with exceptional mechanical properties at both high and low temperatures. Its ability to withstand harsh environments and high-stress applications has made it a popular choice across a range of industries, including aerospace, energy, and marine. Being Nickel 718 a difficult alloy to work using conventional methods, 3D Printing facilitates its usage for a broader range of applications.

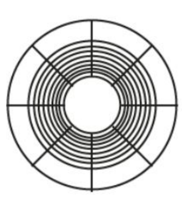
Properties	High Strength, Age-hardenable, High temperature and Corrosion Resistance
Applications	Aerospace, Energy / Oil and Gas and Chemical and Automotive

Wire Chemical Composition	Ni	C	Si	Mn	Cr	Fe	Ti	Mo	Ni+Ta	Al
Weight Percent [%]	Bal.	0.05	0.2	0.2	19.0	20.0	0.9	3.0	5.2	0.5

Wire Density
8.2 g/cm³

Melting Point		
1644 - 1700 K	1371 - 1427 ºC	2500 - 2600 °F

Spool Specs



Meltio Materials are tightly spooled and packaged to ensure the best compatibility with Meltio systems.

Wire Diameter	1.0 mm
Weight on Spool	15 kg
Volume on Spool	1829 cm³
Spool Type	BS300
Wire Coating	Uncoated

Heat Treatment

To achieve the best mechanical properties Nickel 718 should be heat-treated after 3D printing. The standard heat treatment process for Nickel 718 involves two steps: Solution Annealing and Age Hardening. Solution annealing removes internal stresses that have been formed during 3D printing. Machining may take place before or after the solution annealing. Once the component has been age hardened its machinability is compromised.

Solution Annealing

Protective atmosphere Heat up to 1100ºC	Hold for 1h Rapid Cooling in water to RT

Age Hardening

Protective atmosphere Heat up to 760ºC in 2h Hold at 760ºC during 8h	Cool down to 650ºC in 1h50’ Hold at 650ºC during 8h Cooling in oven to RT

**Typical Parameters for a Sample of 160x60x30 mm*

Deposition Parameters

The following 3D printing parameters were found to provide fully dense samples. Please use the provided “Density Profiles” and refer to the document “Printing Parameters and their effect on part density” for additional information.

Laser Power [W]	Velocity [mm/s]	Argon Flow [l/min]	Layer Height [mm]	Wire Speed [mm/s]	Energy Density [J/mm3]
1100	7.5	10	1.0	9.6	147

Meltio Material Datasheet

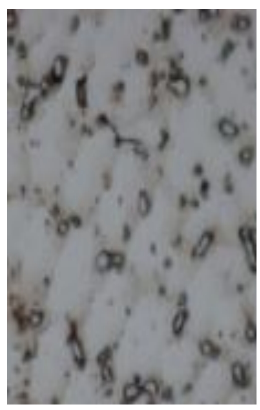
Meltio Nickel 718

ERNiFeCr-2 / S Ni 7718 / 2.4667

Micrography

In the as-printed state of Nickel 718, delta-phase dendrites have been observed within the gamma nickel matrix. Under higher magnification, the presence of intermetallic phases and gamma prime has been noted.

As-printed XY
100x Magnification

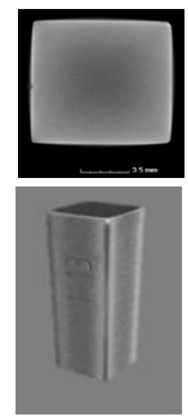


As-printed XY
1000x Magnification

As-printed XZ
1000x Magnification

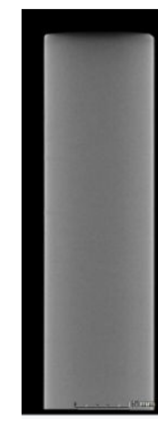
Tomography

Computed Tomography Scan of 3D printed sample part in Inconel 718 without detectable voids or defects. Resolution of 24 µm per pixel.



3D / Top
View

Left View



Front View

Relative density as 3D printed	99.84%

Mechanical Properties

Results show that specimens printed using Meltio's wire-laser metal 3D printed perform at the same level as samples made with conventional manufacturing methods. As-printed testing is carried out in the less favorable XZ direction to ensure the values are applicable across complete part.

			UNE EN ISO 6892-1				
	Cast Properties (AMS 5383)	**Wrought Properties (AMS 5662)**	**Meltio XY properties (S.A. + A.H.)**	**Meltio XZ properties (S.A. + A.H.)**	**Meltio XY properties (S.A.)**	**Meltio XZ properties (S.A.)**	**Meltio XZ Properties (As printed)**
Ultimate Tensile strength (UTS) [MPa]	802	1241	1256 ± 11	1208 ± 49	1016 ± 28	925 ± 86	833 ± 50
Yield strength [MPa]	758	1034	1025 ± 7	980 ± 2	660 ± 10	631 ± 10	537 ± 32
Elongation [%]	5	10	11 ± 1	10 ± 5	18 ± 6	15 ± 2	25 ± 3
			**Test Carried Out In CETEMET* i+d+i@cetemet.es				

			UNE EN ISO 6507-1		
	Cast Properties (AMS 5383)	**Wrought Properties (AMS 5662)**	**Meltio Properties (S.A. + A.H.)**	**Meltio Properties (S.A.)**	**Meltio Properties (As printed)**
***Hardness* [HV-30]**	342	350	332	285	245
			**Tests Carried Out in CETEMET* i+d+i@cetemet.es		

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Meltio Nickel 625

Inconel 625 / ERNiCrMo-3 / S Ni 6625 / 2.4831

Nickel 625 is a superalloy that offers excellent strength, corrosion resistance, and heat resistance. It is a popular material choice in a wide range of applications, including aerospace, chemical processing, and naval industry, where it can withstand high temperatures and harsh environments. Among superalloys, Nickel 625 excels for its weldability, making it an ideal choice for cladding or repair of components working at high temperatures or requiring increased corrosion protection.

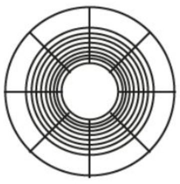
Properties	Weldability, High Temperature Resistance and High Corrosion Resistance
Applications	Aerospace, Chemical Processing,Naval and Oil & Gas

Wire Chemical Composition	Ni	C	Si	Mn	Cr	Fe	Mo	Nb	S
Weight Percent [%]	Bal.	0.02	0.2	0.2	22.0	1.0	9.0	2.5	0.01

Wire Density
8.20 g/cm^3

Melting Point		
1565 - 1625 K	1290 - 1350 ºC	2350 - 2460°F

Spool Specs



Meltio Materials are tightly spooled and packaged to ensure the best compatibility with Meltio systems.

Wire Diameter	1.0 mm
Weight on Spool	15 kg
Volume on Spool	1829 cm^3
Spool Type	BS300
Wire Coating	Uncoated

Heat Treatment

To achieve the best mechanical properties, Nickel 625 should be heat-treated. In Cladding applications heat-treatment may not be required. The standard heat treatment process for nickel 625 involves two steps: Solution Annealing and Age Hardening. Solution annealing removes internal stresses that have been formed during 3D printing. Machining may take place before or after the solution annealing. Once the component has been age hardened to final properties its machinability is compromised.

Solution Annealing

HT.1: Protective atmosphere Heat up to 1050ºC	Hold for 1h Rapid Cooling to RT

Age Hardening

HT.2: Protective atmosphere Heat up to 720ºC in 2h	Hold at 720ºC during 8h Cool down to RT

**Typical Parameters for a Sample of 160x60x30 mm*

Deposition Parameters

The following 3D printing parameters were found to provide fully dense samples. Please use the provided “Density Verified Profiles” and refer to the document “Printing Parameters and their effect on part density” for additional information.

Laser Power [W]	Velocity [mm/s]	Argon Flow [l/min]	Layer Height [mm]	Wire Speed [mm/s]	Energy Density [J/mm3]
1100	10	10	0.8	10.2	138

Meltio Nickel 625

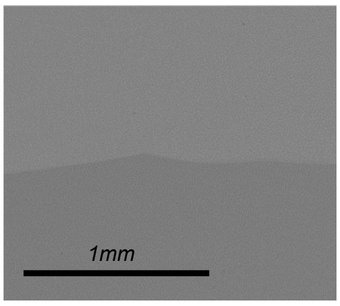
Inconel 625 / ERNiCrMo-3 / S Ni 6625 / 2.4831

Cladding and Dual Material Applications

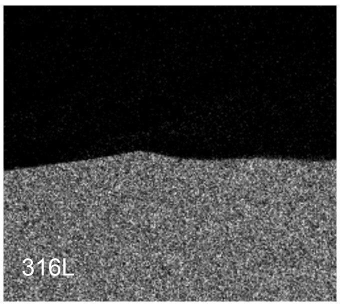
Nickel 625 is highly resistant to wear, deformation and heat, which makes it an excellent material for cladding or dual material applications where not the entire component requires these properties. Nickel 625 has excellent weldability and can be used to form a dense and well-bonded coating layer that provides high wear resistance as well as excellent corrosion and temperature resistance.

Elemental Mapping

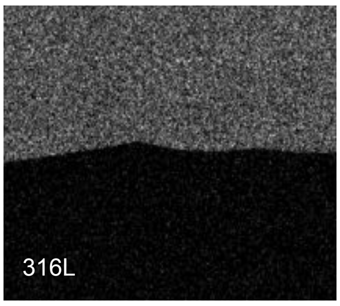
Elemental (EDX) Mapping is employed to characterize the dilution of the two materials. Meltio used as deposited Stainless Steel 316L as the substrate without post processing. Results show low dilution between the materials.



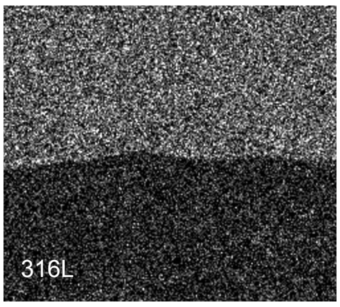
Cladding interface layer XZ
Electron Microscopy



Cladding interface layer XZ
Iron EDX Map



Cladding interface layer XZ
Nickel EDX Map

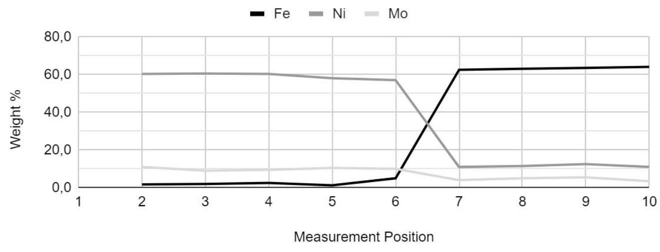


Cladding interface layer XZ
Molybdenum EDX Map

Elemental Distribution

Composition Mapping of Nickel 625 Cladding on SS316L. Measurements were spaced 150 µm.Apart with measurement 5 coinciding with the interface of the two materials.

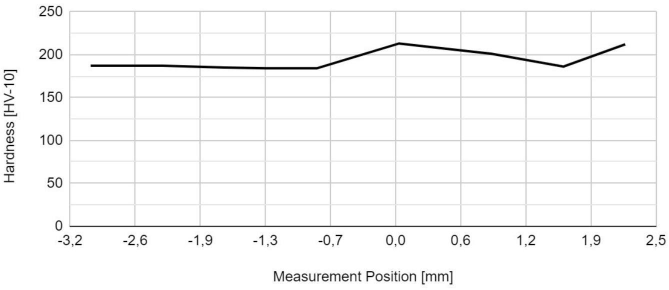
Measurement [Position]	Nb [wt%]	Mo [wt%]	Mn [wt%]	Fe [wt%]	Ni [wt%]
1	3.5	11.0	0.5	1.8	60.3
2	3.8	9.0	0.1	2.0	60.5
3	4.0	9.5	0.5	2.5	60.3
4	6.5	10.5	0.8	1.3	58.0
Interlayer					
5	4.0	10.0	0.5	5.0	57.0
6	0.5	4.0	1.5	62.5	11.0
7	1.5	5.0	1.0	63.0	11.5
8	0.5	5.5	1.5	63.5	12.5
9	0.5	3.5	1.5	64.0	11.0
10	1.0	4.0	1.5	64.5	11.5



Hardness Profile

Hardness was measured across the material transition and results indicate that a single cladding layer is sufficient to achieve good and stable properties.

Hardness [HV10]	Distance [mm]	Material [txt]
212	2.2	Nickel 625
186	1.6	
201	0.9	
213	0.0	**Interlayer**
184	-0.8	Stainless Steel 316L
184	-1.3	
185	-1.7	
187	-2.3	
187	-3.0	



** Meltio's work on material characterization is carried out using the Meltio M450 and it remains under constant development. Specifications provided herein may not reflect the latest state of our research. For further information and questions please contact us via info@meltio3d.com.*

*** Any technical information or assistance provided herein is given and accepted at your own risk and neither Meltio nor its affiliates make any guarantees relating to it or because of it. Neither Meltio nor its affiliates shall be responsible for the use of this information, or any product, method or apparatus mentioned and you must make your own determination for its suitability and completeness for you application. Specifications are subject to change without notice.*

Meltio Tool Steel H11

Tool Steel H11 / 1.2343

Tool Steel H11 is one of the most commonly used tool steels. It is a hot-work steel that is used to make hot-working tools such as forging, die-casting, extrusion, and plastic molds due to its resistance to thermal fatigue cracking and high-temperature abrasion. In addition to hot-working tools, it is also used to produce cutting tools and in the aerospace industry for mechanical components.

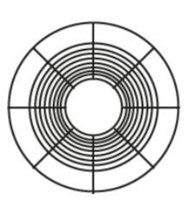
Properties	High Strength, High Temperature Resistance and High Hardness
Applications	Aerospace Components, Cutting Tools and prototypes and Molds and Dies

Wire Chemical Composition	Fe	C	Si	Mn	Cr	Mo	V
Weight Percent [%]	Bal.	0.38	1.0	0.4	5.0	1.1	0.45

Wire Density
7.81 g/cm³

Melting Point		
1753 K	1480 ºC	2700°F

Spool Specs



Meltio Materials are tightly spooled and packaged to ensure the best compatibility with Meltio systems.

Wire Diameter	1.0 mm
Weight on Spool	15 kg
Volume on Spool	1920 cm³
Spool Type	BS300
Wire Coating	Copper

Heat Treatment

Tool Steel H11 is an Air-Hardening tool steel which during 3D printing reaches its hardened state. In this state machinability is affected and there is a high risk of cracking due to the reduced ductility. Consequently, a heat-treatment cycle is typically necessary, except for cladding applications or small feature addition. The ideal cycle should begin with an annealing step prior to removing the part from the build plate. The material will be softened and free of internal stresses, making easy to machine. After machining, the part should then undergo hardening and a suitable tempering cycle to achieve the desired hardness.

Annealing

HT.1: Argon atmosphere Heat up to 820ºC	Slow Cooling in oven to RT

Age Hardening

HT.2: Argon atmosphere Heat up to 1025ºC	Hold for 2h Forced Air-cooling to RT

Tempering

HT.3 (Example): Argon atmosphere Heat up to 550ºC	Hold for 1h Slow Cooling to RT (Repeat 2x)

**Typical Parameters for a Sample of 160x60x30 mm*

Deposition Parameters

The following printing parameters were found to provide fully dense samples. Please use the provided “Density Profiles” and refer to the document “Printing Parameters and their effect on part density” for additional information.

Laser Power [W]	Velocity [mm/s]	Argon Flow [l/min]	Layer Height [mm]	Wire Speed [mm/s]	Energy Density [J/mm3]
1100	7.5	10	1.0	9.6	147

Meltio Tool Steel H11

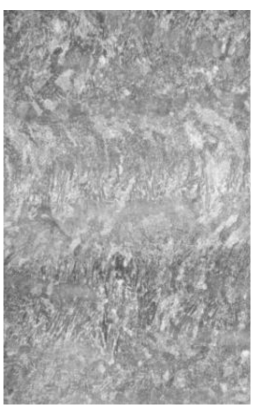
Tool Steel H11 / 1.2343

Micrography

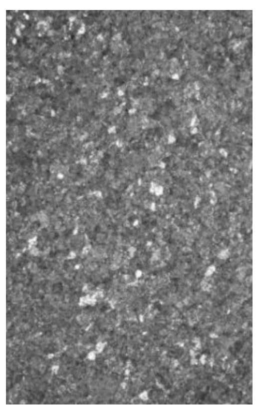
Tool Steel H11 displays tempered and fresh martensite, retained austenite, and columnar grain morphology aligned with the solidification front. Heat treatment reduces retained austenite and refines the grain to a primarily equiaxed shape, converting most of the martensite. Trace amounts of austenite may remain undetectable with light microscopy.

Tomography

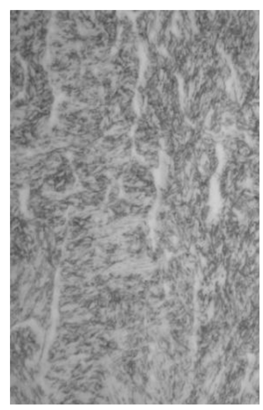
Computed Tomography Scan of 3D printed sample part in H11 without detectable voids or defects. Resolution of 24 µm per pixel.



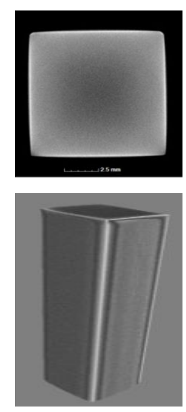
As-printed XZ
100x Magnification



HT.1 + HT.2 + HT.3 XZ
100x Magnification



As-printed XZ
1000x Magnification



3D / Top View

Left View

Front View

Relative density as 3D printed	99.89%

Mechanical Properties

Results show that specimens printed using Meltio's wire-laser metal 3D printed process perform at the same level as samples made with conventional manufacturing methods. Testing is carried out in the less favorable XZ direction to ensure the values are applicable across complete part.

		UNE EN ISO 6892-1	
	Wrought Properties (ASTM 1472)	**Meltio XZ Properties (HT.1 + HT.2 + HT.3)**	**Meltio XZ Properties (As Printed)**
Ultimate Tensile strength (UTS) [MPa]	1990	2087 ± 2	1830 ± 105
Yield strength [MPa]	1650	1735 ± 101	1170 ± 90
Elongation [%]	10	12.18 ± 0.19	3.46 ± 0.36
		*Tests Carried Out In IDONIAL info@idonial.com	

		UNE EN ISO 6507-1	
	Wrought Properties (ASTM 1472)	**Meltio Properties (HT.1 + HT.2 +HT.3)**	**Meltio Properties (As Printed)**
Hardness [HRC]	53	51	52
		*Tests Carried Out In IDONIAL info@idonial.com	

Meltio Material Datasheet

Meltio Tool Steel H11

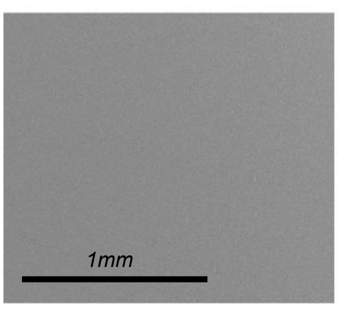
Tool Steel H11 / 1.2343

Cladding and Dual Material Applications

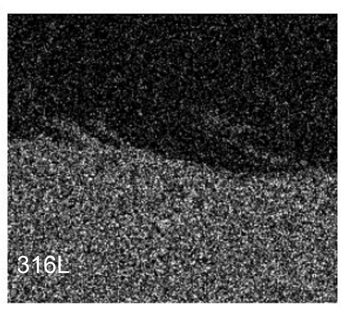
Tool Steel H11 is highly resistant to wear, deformation and heat, which makes it an excellent material for cladding or dual material applications where not the entire component requires these properties. H11 steel has excellent weldability and can be used to form a dense and well-bonded coating layer that provides high wear resistance, high Hardness and temperature resistance as well as good corrosion resistance.

Elemental Mapping

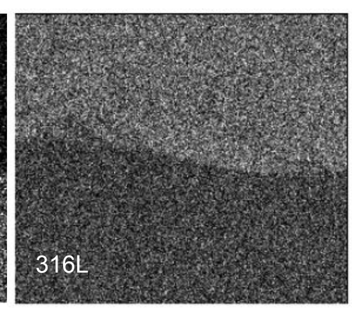
Elemental (EDX) Mapping is employed to characterize the dilution of the two materials. Meltio used as printed Stainless Steel 316L as the substrate without post processing. Results show low dilution between SS316L and H11.



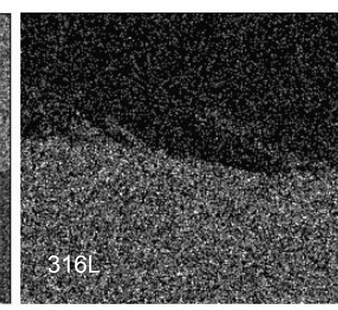
Cladding interface layer XZ
Electron Microscopy



Cladding interface layer XZ
Chromium EDX Map



Cladding interface layer XZ
Iron EDX Map

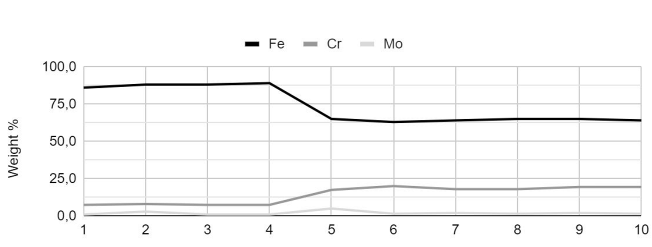


Cladding interface layer XZ
Nickel EDX Map

Elemental Distribution

Composition mapping of H11 cladding on SS316L. Measurements were spaced 150 µm. Apart with measurement 5 coinciding with the interface of the two materials.

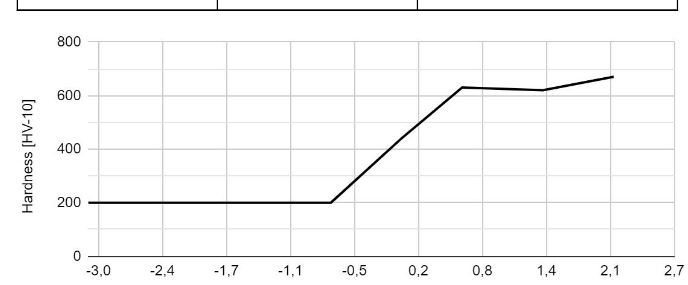
Measurement [Position]	Mo [wt%]	Cr [wt%]	Mn [wt%]	Fe [wt%]	Ni [wt%]
1	1.0	7.5	1.0	86.0	4.0
2	3.0	8.0	2.0	88.0	4.0
3	1.0	7.5	1.0	88.0	2.0
4	1.0	7.5	1.0	89.0	2.0
Interlayer					
5	5.0	17.5	1.0	65.0	10.0
6	1.5	20.0	1.0	63.0	14.0
7	2.0	18.0	2.0	64.0	11.0
8	1.5	18.0	1.0	65.0	13.0
9	2.0	19.5	1.0	65.0	11.0
10	1.5	19.5	1.0	64.0	12.0



Hardness Profile

Hardness was measured across the material transition and results indicate that a single cladding layer is sufficient to achieve good and stable properties.

Hardness [HV10]	Distance [mm]	Material [txt]
670	2.1	Tool Steel H11
620	1.4	
630	0.6	
440	0.0	**Interlayer**
200	-0.7	Stainless Steel 316L
200	-1.4	
200	-1.8	
200	-2.2	
200	-3.1	



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Meltio Titanium 64

Ti-6Al-4V / ER Ti-5 / S Ti 6402c / 3.7165

Ti64 is a popular and widely used alloy due to its excellent combination of strength, low density, and corrosion resistance. It is used in a variety of industries, including aerospace, and chemical processing, due to its properties. Its high strength-to-weight ratio makes it a preferred choice for lightweight applications.

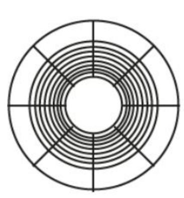
Properties	High Strength, Low Weight and Corrosion Resistance
Applications	Aerospace, Marine, Chemical industries and Automotive

Wire Chemical Composition	Ti	Al	V	Fe	C	N	H	O
Weight Percent [%]	Bal.	5.5	3.5	0.4	0.08	0.05	0.015	0.2

Wire Density
4.4 g/cm³

Melting Point		
1947 K	1674 ºC	3045 °F

Spool Specs



Meltio Materials are tightly spooled and packaged to ensure the best compatibility with Meltio systems.

Wire Diameter	1.0 mm
Weight on Spool	7.5 kg
Volume on Spool	1704 cm³
Spool Type	BS300
Wire Coating	Uncoated

Heat Treatment

Heat treatment is recommended for Ti64 to enhance its mechanical properties. Through heat treatment, the alloy becomes stronger, more ductile, and more resistant to fatigue, making it suitable for high-stress applications. Heat treatment also eliminates residual stresses and helps to refine the microstructure of the alloy, leading to improved toughness and increased resistance to crack growth. Heat treatment of Ti64 after 3D printing is a crucial step in maximizing its performance in applications.

Age Hardening

Vacuum atmosphere Heat up to 920ºC Hold at 920ºC during 2h	Cool to 400ºC during 10h Cold down to RT

Age Hardening

Vacuum atmosphere Heat up to 920ºC 103 MPa of pressure	Hold for 2h Cold down to RT

**Typical Parameters for a Sample of 160x60x30 mm*

Deposition Parameters

The following 3D printing parameters were found to provide fully dense samples. Please use the provided “Density Profiles” and refer to the document “Printing Parameters and their effect on part density” for additional information.

Laser Power [W]	Velocity [mm/s]	Argon Flow [l/min]	Layer Height [mm]	Wire Speed [mm/s]	Energy Density [J/mm3]
1100	7.5	20	1.0	9.6	147

Meltio Material Datasheet

Meltio Titanium 64

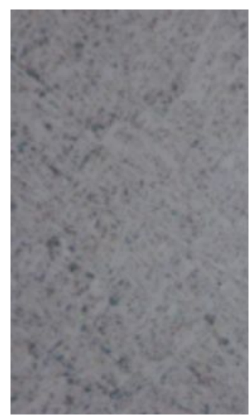
Ti-6Al-4V / ER Ti-5 / S Ti 6402c / 3.7165

Micrography

The observed microstructure is composed of acicular martensite embedded in the beta phase. The columnar shape of the grains extends along the manufacturing direction due to epitaxial growth of the original beta phase. In the XY section, the microstructure appears as polyhedral grains of α´ + β, with alpha phases at grain boundaries.

As-printed XY
100x Magnification

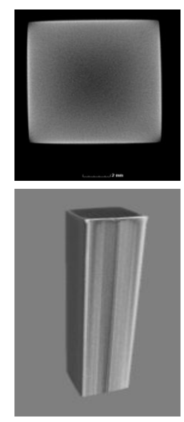
As-printed XY
1000x Magnification



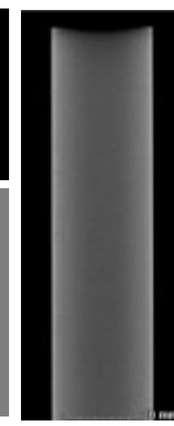
As-printed XZ
1000x Magnification

Tomography

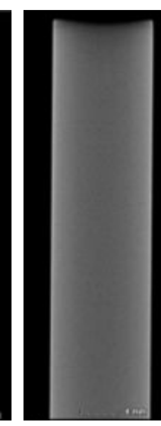
Computed Tomography Scan of 3D printed sample part in Ti64 without detectable voids or defects. Resolution of 24 μm per pixel.



3D / Top View



Left View



Front View

Relative density as 3D printed	99.994%

Mechanical Properties

Results show that specimens printed using Meltio's wire-laser metal 3D printed process perform at the same level as samples made with conventional manufacturing methods. Results show low deviations and near isotropic properties after heat treatment. As printed data is not shown as it is not industrially relevant.

			UNE EN ISO 6892-1	
	Cast Properties (ASTM F1108)	**Wrought Properties (ASTM F1472)**	**Meltio XY properties (Age Hardened)**	**Meltio XZ properties (Age Hardened)**
Ultimate Tensile strength (UTS) [MPa]	860	930	802 ± 7	788 ± 12
Yield strength [MPa]	758	860	727 ± 17	693 ± 16
Elongation [%]	8	10	7 ± 1	9 ± 1
			**Test Carried Out In IDONIAL* i+d+i@cetemet.es	

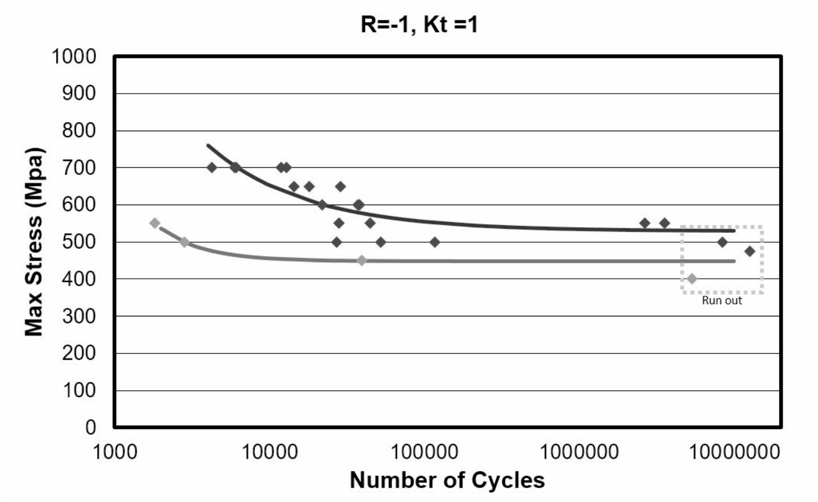
			UNE EN ISO 6507-1	
	Cast Properties (ASTM F1108)	**Wrought Properties (ASTM F1472)**	**Meltio (Age Hardened)**	**Meltio Properties (As printed)**
Hardness [HV-30]	342	349	311	303
			**Test Carried Out In the University of Jaen (UJA)* info@strainanalysisuja.es	

Meltio Titanium 64

Ti-6Al-4V / ER Ti-5 / S Ti 6402c / 3.7165

Fatigue

Meltio carried out a fatigue study on 3D printed specimens using two heat treatments, namely age hardening and hot isostatic pressing. The presence of residual porosity in the sample parts during the study, which has been resolved through process improvements, may explain the difference in fatigue behavior between the age-hardened and hot isostatic pressed specimens.



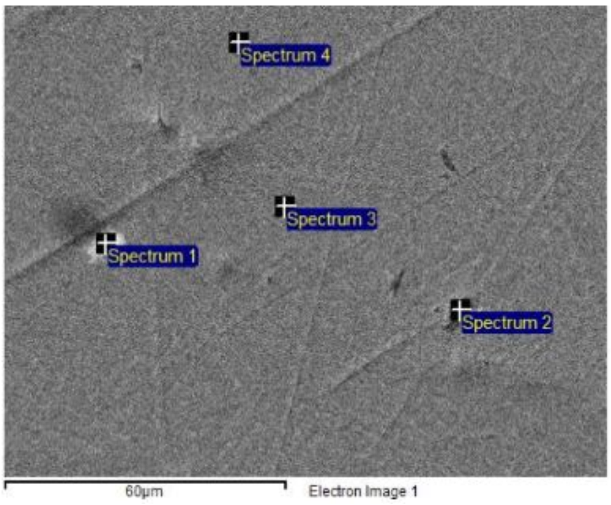
Fatigue Strength

			UNE-EN ISO 1143	
	Cast Properties (ASTM E466)	**Wrought Properties (ASTM E466)**	**Meltio XZ properties (Age Hardened)**	**Meltio XZ properties (Hot Isostatic Pressing)**
Fatigue Strength 10^7 Cycles [MPa]	310	560	450	530

Oxidation

Oxidation is a crucial factor that particularly affects the properties and performance of 3D printed titanium samples. Titanium has a high affinity for oxygen when exposed to air at high temperatures, which leads to embrittlement and reduced mechanical properties, such as decreased resistance to wear, fatigue, and corrosion.

Manufacturing parts in the Meltio M450 with only local gas shielding from the laser head resulted in components with 0.25 % in oxygen content. The SEM image showed dispersed oxides, including rutile and alumina and EDX spectra revealed the presence of titanium and aluminum oxides.



Spectrum	In stats.	O	Al	Ti	V	Total
Spectrum 1	Yes	62.00	6.74	31.26		100.00
Spectrum 2	Yes	52.16	35.61	12.23		100.00
Spectrum 3	Yes	53.14	24.32	22.54		100.00
Spectrum 4	Yes		7.14	89.69	3.17	100.00

SEM Image in XY plane at 1000x magnification

** Meltio's work on material characterization is carried out using the Meltio M450 and it remains under constant development. Specifications provided herein may not reflect the latest state of our research. For further information and questions please contact us via info@meltio3d.com.*

Meltio Invar 36

Invar 36 / Alloy 36 / 1.3990

Invar is a type of nickel-iron alloy that is known for its unique properties, including low coefficient of thermal expansion and high dimensional stability over a wide range of temperatures. These characteristics make it a valuable material in various applications that require precision and stability, such as precision instruments, scientific measuring devices, cryogenics, composite molds and aerospace components.

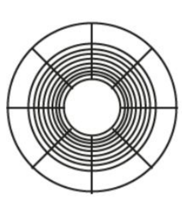
Properties	Extremely low coefficient of thermal expansion and High Strength at low temperatures
Applications	Aerospace, Precision Components and Cryogenic Components

Wire Chemical Composition	Fe	C	Ni	Mn	Nb	Ti
Weight Percent [%]	Bal.	0.35	36.0	1.0	2.5	1.0

Wire Density
8.10 g/cm^3

Melting Point		
1613 K	1340 ºC	2445°F

Spool Specs



Meltio Materials are tightly spooled and packaged to ensure the best compatibility with Meltio systems.

Wire Diameter	1.0 mm
Weight on Spool	15 kg
Volume on Spool	1851 cm^3
Spool Type	BS300
Wire Coating	Uncoated

Heat Treatment

Owing to the use of Invar in precision components, it is often recommended to subject it to an annealing heat-treatment after 3D printing. This is necessary as the 3D printing process introduces residual stresses, which affects the material's performance. After annealing, the sample should pass through an aging process to improve and achieve suitable mechanical properties.

Annealing

Protective atmosphere Heat up to 800ºC	Hold for 1h Slow Cooling to RT

Aging

Protective atmosphere Heat up to 425ºC	Hold at 425ºC during 2h Cooling in oven to RT

**Typical Parameters for a Sample of 160x60x30 mm*

Deposition Parameters

The following 3D printing parameters were found to provide fully dense samples. Please use the provided “Density Profiles” and refer to the document “Printing Parameters and their effect on part density” for additional information.

Laser Power [W]	Velocity [mm/s]	Argon Flow [l/min]	Layer Height [mm]	Wire Speed [mm/s]	Energy Density [J/mm3]
1100	7.5	10	0.8	7.64	183

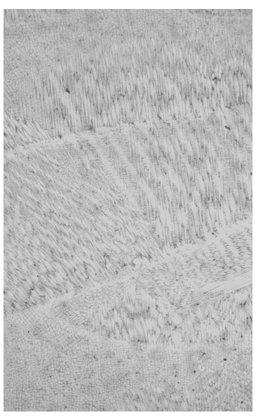
Meltio Material Datasheet

Meltio Invar 36

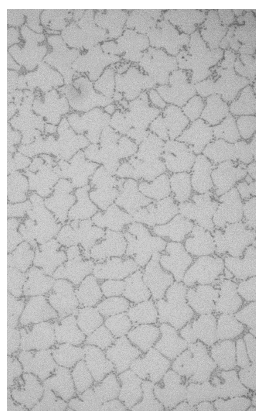
Invar 36 / Alloy 36 / 1.3990

Micrography

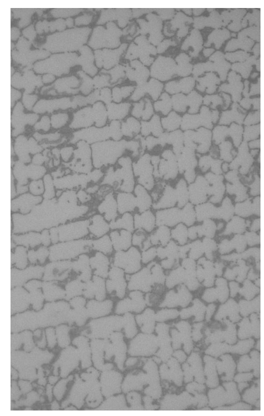
The as printed microstructure of Invar is heterogeneous and mostly austenite with nickel dissolving in γ-Fe.



As-printed XZ
100x Magnification



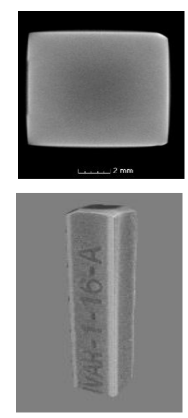
As-printed XZ
1000x Magnification



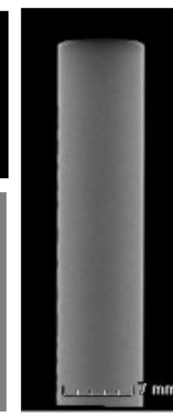
As-printed XY
1000x Magnification

Tomography

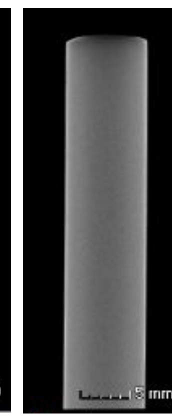
Computed Tomography Scan of 3D printed sample part in Invar without detectable voids or defects. Resolution of 24 μm per pixel.



3D / Top View



Left View



Front View

Relative density as 3D printed	99.99%

Mechanical Properties

Results show that specimens printed using Meltio's wire-laser metal 3D printed process perform at a high level when compared to samples made with conventional manufacturing methods. Testing is carried out in the less favorable XZ Direction to ensure the values are applicable across complete part.

		UNE EN ISO 6892-1
	Wrought Properties (ASTM A658)	**Meltio XZ Properties (As Printed)**
Ultimate Tensile strength (UTS) [MPa]	500	522 ± 14
Yield strength [MPa]	241	337 ± 22
Elongation [%]	31	24 ± 2
		**Tests Carried Out in CETEMET* *i+d+i@cetemet.es*

		UNE EN ISO 6507-1
	Wrought Properties (ASTM A658)	**Meltio Properties (As Printed)**
Hardness [HV-30]	127	147
		*Tests Carried Out In IDONIAL info@idonial.com

** Meltio's work on material characterization is carried out using the Meltio M450 and it remains under constant development. Specifications provided herein may not reflect the latest state of our research. For further information and questions please contact us via info@meltio3d.com.*

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