

Agenda

MFFF process

Recap – application sweet spot

Metal parts characteristics

mFFF process training

Ultimaker Metal Expansion Kit



UltiMaker ofrece soluciones y flujos de trabajo de fabricación aditiva (extrusión) para la creación de prototipos, utillajes y producción de series pequeñas de componentes auxiliares



From PLA to Elastomers to Composites to Metal applications

Knowledge & Support services

Save costs up to 90% when sourcing small series of small metal auxiliary components and functional prototypes with the Ultimaker MFFF 3D printing solution for 1199,00 EUR





Metal parts with Ultimaker? how?

MFFF – METAL FUSED FILAMENT FABRICATION

D&S – DEBINDING & SINTERING

MIM – METAL INJECTION MOLDING



Metal FFF on open systems is recognized as low-cost solution for small volumes of nonstandard auxiliary components and functional prototypes



Metal Injection Molding Process



Complex shapes

Small (below 15 cm)

Thousands of parts x order







Metal FFF on open systems is recognized as low-cost solution for small volumes of nonstandard auxiliary components and functional prototypes



Metal FFF on desktop printers relies on 30 years of experience of the Metal injection molding process





Why can we process highly charged filaments (>60 vol%)?



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Process Workflow Catalytic Debinding: The "Cata" in Catamold®



Catalytic Debinding

- Removal of the majority of plasticizer before sintering
 Depolymerization of primary binder (POM)
 Secondary binder is unaffected (Polyolefin)
- Complete gas phase reaction
- Only catalytical quantities of acid required

Depolymerization of primary binder (POM)









Process Workflow Sintering in reducing environment







Sintering

- Thermal debinding of secondary binder
 - Necking metal particles stabilize the structure
- Compacting and forming a solid mass without melting
- Part shrinks due to densification
- Generic shrinkage ranges:
 - XY direction -16%
 - Z direction -20%



General Part Size

Max Build Volume for D&S Service

Technical Limitations (Elnik Systems)

- Size of the Furnace (120L)
- Size of the shelf (300*200mm²)
- Size of the ceramic plate (150*100mm²)







44 shelfs Shelf spacing: 38mm

Shelf size: 206*305mm² Ceramic plates:

> $200*300 \text{ mm}^2$ $200*150 \text{ mm}^2$ $\rightarrow 100*150 \text{ mm}^2$

Sintering

Evolution of microstructure





Application sweet spot



Applications sweet spot in MFFF?



In which situations does the MFFF can be considered as an alternative manufacturing technology?



In-house DMLS / CNC capacity is not accessible/convenient for lower end components

Which problems is MFFF trying to solve?

Reduce costs and leadtime of small series components and manufacturing aids

Access higher complexity metal parts at no additional cost

Reproducible, implementable & low TCO Process

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1. Reduce costs and leadtime for certain small series and manufacturing aids



Metal FFF on open systems is recognized as low-cost solution for small volumes of nonstandard auxiliary components and functional prototypes



Low volumes of not standard parts by MFFF yields accurate up to 90% savings at a comparable leadtime vs traditional manufacturing



Comparable leadtimes

-34% costs vs outsourced MFFF

-75% costs vs next best alternative

-83% costs vs cheapest CNC offer

In-house MFFF

Online machine shops

Local machine shops

Option	Service Provider	Country	Manufacturing Technology	U	nit price	Тс	otal price	Part Leadtime	Quote Leadtime	Total costs vs Option 1	MFFF savings (%) vs other options
1	In-house	NL	MFFF	€	28,30	€	84,90	15 days -			
2	Sculpteo	online	MFFF	€	42,82	€	128,46	17 days	-	+€43,56	34%
3	Protolabs	online	DMLS	€	116,00	€	346,26	15 days	-	+€261,36	75%
4	Protolabs	online	CNC	€	541,00	€	1153,26	21 days	-	+€1.068,36	93%
5	Xometry	online	DMLS	€	171,50	€	513,00	19 days	-	+€428,10	83%
6	Xometry	online	CNC	€	162,50	€	487,00	27 days	-	+€402,10	83%`\
7	3Dhubs	online	CNC	€	181,00	€	543,00	23 days	-	+€458,10	84%
8	workshop	Germany	CNC	€	99,00	€	297,00	20-25 days	2 days	+€212,10	71%
9	workshop	US	CNC	\$	200,00	\$	600,00	20 days	2 days	+ \$ 515,10	86%
10	workshop	NL	CNC	€	316,00	€	948,00	20 days	6 days	+€863,10	91%

Printer to printer precision and each component accuracy remains within \pm 0.3 mm tolerance range

Pass / No Pass filter at ± 0.3 mm



When the guidelines are respected...





2. Access complexity at no extra costs



MFFF enable higher freedom of design and additional functionalities vs CNC e DMLS without additional costs and at 5% of the investment

Interlocked assemblies	Embedded cooling channels	Embedded high-surface area	Organic shapes via generative design	Functional surface texture	Embedded hollow structures
MFFF					
DMLS					
MIM					
CNC					



MFFF on Ultimaker enable higher freedom of design and additional functionalities thanks to the integration of new accessories, materials and CAM features in CURA







3. Accessible, traceable and low TCO



3. Reproducible, implementable and low TCO



ROI < 2 years



Access to Professional Network of D&S service

No need to insource D&S in-house

Stable & reliable supplier & Process



BASF-Ultimaker Partnership

Industrial standard Services



Material properties

Which metal grades and materials can be printed on Ultimaker?

Ultrafuse® 17-4 PH vs. Ultrafuse® 316L

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- Ultrafuse® 17-4 PH has higher mechanical properties and hardness. This makes it more suitable for general use. Higher hardness could be achieved with heat treatment.
- Ultrafuse® 316L has higher corrosion resistance which makes it a material of choice for applications in humid and salty environments.



Access to industrial grade filaments, D&S service and new CURA 5.1 features allowed to obtained high quality martensitic (17-4PH) and eustenic (316L) microstructures

Porosity of final metal parts below 4%



Martensitic precipitation hardened stainless steel containing approximately 15–17.5% chromium and 3–5% nickel, as well as 3–5% copper

Ultimaker

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Mechanical properties of 17-4PH printed parts reflects values from traditional manufacturing technologies



	MFFF ¹ (xy/zx)	MIM ²	CNC ³
Ultimate Tensile Strength (MPa)	990/1004	790	896 - 990
Yield strength Rp 0.2 (MPa)	756/764	650	827 - 914
Young s modulus (GPa)	190-195	190-200	197 - 207
Hardness (HV10)	291		250 - 260
Carbon concentration	<0.03 %	<0.03 %	<0.03 %
Average density	>96% of Bulk	98.08% of Bulk	99.99%

¹**MFFF:** Ultrafuse[®] 17-4PH TDS (Numbers refer to printed dogbones) ²**MIM:** Catamold [®]17-4PH TDS ³**CNC:** Hubs



Best practises and operational guidelines






How customers must gain access to Academy and other digital resources

The Getting Started Portal



Users don't need to start metal printing on a dedicated Metal printer. Ultimaker S-line is now validated to fully support metal printing



Perform print core cleaning with provided cleaning sticks



Preferences | *Maintenance* | *Print head* | *Print core cleaning*

Print core lifetime

Perform print core cleaning with provided cleaning sticks

Firmware 7.04 addition

- Mark print cores as "tainted"
- Tainted means the max temperature is limited
- Warning pop-up with option to start Print core cleaning wizard
- Designed to prevent print cores from clogging







Build plate adhesive and material storage

First layer

• Apply even coat of Magigoo Metal to cold build plate *Glue can be washed down the drain

BASF Ultrafuse metal filaments are not hygroscopic

- Can easily be stored in a cabinet without desiccant solutions
- Can print without drying / moisture-controlling devices





Filament feeder tension

Filament feeder pushes the filament into the printhead

- Pressure of the filament against the feeder gear is critical
 - Too low show inconsistent flow
 - Too high damages the filament
- Feeder pressure should be in the top half
- Fine knurl feeder gears are recommended (less grinding)
 - Already installed in all S-line printers since Feb-2021
 - Otherwise, Fine knurl feeder kit is needed
 - <u>Installation guidelines</u>







Release from buildplate



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*Must use water soluble glue





- Be patient!
- Do not attempt to forcibly remove part from build plate
- Water can go down standard drain



Post-processing

Water bath and tray

Effortless release of the part from build plate





Post-printing & finishing



Final cleaning before shipment

Clean off any foreign material with water





Residual glue was not cleaned off before shipping and shows up after debind and sintering

*Make sure to dry all parts before shipment



Post-printing

Clean up 3D printed parts

Green parts are easily post processed

- Sanding, drill, milling, sandblasting, etc.
- As with any manufacturing process PPE is required!



Bead blasting

Required equipment & blasting media



Finish after sintering

Wet sand, polish, paint







Requesting D&S service





EU: via Elnik GmbH and BASF D&S Portal





How to access the network of D&S professionals

D&S service steps User steps Shipment Create order Check next Print parts (according to deadline) D&S round Ultimake Itimal 1-2 Business days • 1x D&S Coupon allows user to Process up to a cumulative **D • BASF** • 1kg of green parts sent within the same shipment Ultrafuse 17-4 PH • And include back shipment (9.99 EUR) Examples: a. <u>600 gr green parts to D&S = 1 ticket (1 shipment)</u> b. <u>1.2Kg</u> green parts to D&S = 2 tickets (1 shipment) **D&S** Coupon Ultimaker 54

BASF Online platform



Reduce number of steps and avoid improvised solutions to complete many of those auxiliary steps in the process





Dry or remove any type of residue from the green part

Weight and measure part dimensions

Wrap green part singularly with provided bubble wrap

Place the wrapped parts in the Provided Box

Verify parts do not move in the box. Add more bubble wrap to avoid parts movements during shipment

How to access the network of D&S professionals

User steps

D&S service steps





How to control part quality during print job preparation



..... siguiendo las pautas y haciendo el proceso MFFF en Ultimaker



Mistakes in printing strategy only become visible during post-processing Case: unsupported thin walls



Major failure modes during D&S



Using Ultimaker CURA 5.1 allows superior printing performance thanks to the new Arachne engine and the addition of dedicated Metal printing features







Ultimaker Cura 4.13

Ultimaker Cura 5.0

Failure mode A/B: increasing stability of thin walls

CURA 4.x



CURA 5.x



Failure mode C/D: Why metal parts distort, twist during sintering?





High temp Post-processing steps Layer by layer deposition methods of semi-crystalline polymers creates abrupt stress relaxation in solids

Origin of deformation in metal printed parts after D&S





→ Higher internal stresses build-up

- Stress release induces part distortion
- Distortion is a spontaneous reaction occurring at T > Tg
- PE and POM Tg = -120C and -70C
- Major distortion occurring during Sintering (PE)



Same directions



Reverse direction

CURA 5.1 can alternate outer walls direction to minimize accumulation of stresses in one direction in 2 ways



Failure mode C/D : Alternated walls in CURA 5.1









CURA 5.1 With Alternated walls

CURA 4.13

Without Alternated walls

Distortions



Reduce distortions using a shrinkage plate



Support Strategy

Shrinkage Plate

Shrinkage is affected by design

- Shrinkage is driven by material consolidation
- Weak diffusional forces
- Bottom part is affected by static friction
- Every part feature shrinks to its center of gravity









Shrinkage plate homogenizes shrinkage values throughout the part and increases part accuracy

Multiple centres of gravity (different shrinkage values x area)



Uniformed centre of gravity – shrinkage plate (uniformed shrinkage value)





Additional best practises to reduce internal stresses and cracks


Failure mode E : cracks and collapse











Maximum part size: Parts should be no larger than 100 x 100 x 100 mm

Thin features: Thin walls thickness (A) should be a multiple of the nozzle diameter. (min 0.8 mm)

Sharp corners: They act as stress concentrators and line splitting areas. Round corners and addition of chamfers to be preferred Maximum feature thickness: Features' thickness should not exceed the debinding process penetration depth limit of 30 mm Height to width ratio: Height to width ratio no larger than 3:1 prevents collapse and distortion

Overhangs:

Ensure that all overhanging areas are properly supported to avoid collapse during debinding

Automatically done in Ultimaker Cura 5



- Selection in preview mode shows original size of the part
- No manual scaling needed in Cura 5

Material			\sim
Scaling Factor Shrinkage Compensation	Ċ	100.0	96
Horizontal Scaling Factor Shrinkage Compensation	õ	119.0	96
Vertical Scaling Factor Shrinkage Compensation	Ċ	125.0	%





Overhangs and support strategies



Since Support layer material (white) doesn't shrink, it needs to be as thin as possible in order to reduce the effect of shrinkage % mismatch with the Object and supports Support material strategy



Green part preparation on Ultimaker CURA 5.1 is automated



G UMS5_EMEA_GripperBodies(x2)_14h58m_378g - Ultimaker Cura

Edit <u>V</u>iew Settings Extensions P<u>r</u>eferences <u>H</u>elp File Ultimaker Cura PREPARE PREVIEW MONITOR Marketplace Sign in Ultrafuse Support Lay... DD 0.4 Ultrafuse 17-4PH 105% 🕅 On 👲 On 2 Normal - 0.15mm Ultimaker S5 \sim \sim \sim CC 0.4 \$ X -9.2573 mm Y 12.5 mm 3 Ζ 0 mm 5 Ultimaker 55 Lock Model • 0. Object list 2 UMS5_EMEA_GripperBodies(x2)_14h58m_378g 38.3 x 63.1 x 49.4 mm Slice 00000

Ultimaker Cura marketplace

Downloading material print profiles

Preconfigured printing profiles:

- Standard
 - Tuned for maximum density, high mechanical strength, medium feature detail
- Lightweight
 - Reduces part mass and printing time while maintaining acceptable structural integrity

Ultimaker Marketplace			
Cura Plugins Digital Fac	ctory Integrations	Materials	
♥ Filters BASF metal	م	"BASF Metal" In Materials 30 results	
Brand Polymer class Material characteristic Filling Printer type Print Core / Nozzle Certified ③ Material Station com	V V V V	Ultrafuse 17-4PH By BASF Forward AM Metal-polymer composite filament to produce metal components in a stainless-steel type 17-4PH with subsequently an industry-standard	
Air Manager optimize	ed		

Cura 5.0 – FW up to 7.0.3	Cura 5.1 – FW 7.0.4
CC04 and CC06 compatibility	CC04, CC06 and DD04 compatibility
Ultrafuse 17-4PH profiles	Ultrafuse 17-4PH profiles + Ultrafuse Support Interface Layer profile



General Part Size

Max Build Volume for D&S Service

Technology Limitations

Shrinkage: Friction > Diffusional forces

- Center of gravity
- Weight distribution
- Accuracy
- Debinding penetration
- Form outside to inside
- Homogenous heat distribution
- Thin and thick features



100 mm = ~4"

Individual Component Details

Walls and Outlines

- Recommended minimal wall thickness: (A=0.8mm for CC04, 1.2mm for CC06)
- Recommended maximum wall thickness: 30mm wall thickness– max. 24h (1-2mm/h Maximum size)



Individual Component Details

Walls and Outlines

Unsupported Thin Walls

• To minimize the chance of structural collapse, height to width ratios no greater than 6 to 1 have been proven to be effective





Example: Thin Wall Test

• Although easily printable, thin unsupported walls can fail when greater than 6:1



⁸² * Line width



How to get started

The Ultimaker metal expansion kit includes:



What do customers need to get started with MFFF successfully

All validated and connected workflow items

Ultimaker Metal Expansion Kit

Open Access





Brown part stability simulation in Fusion 360



Virtual Engineering workflow

Simulation



Design guide informed by simulation

Overhangs (More Support for D&S)

• A greater need for supports is required in D&S than in printing

Brown Part Stability

• Brown Part Stability helps to detect highly stressed areas to make design changes







Design guide informed by simulation – meshing

- 1. Load the part file into the chosen CAD software
- 2. Ensure that the appropriate printing oversizing scale has been applied
- 3. Rotate the part according to the print orientation (global z-direction is the print direction)
- 4. Mesh the part using 3D solid elements (tetrahedrons, hexahedrons, etc.)
- 5. Ensure that a minimum of 3 mesh elements are present across the thinnest part features (the finer mesh the higher accuracy, but at the cost of calculation time)

Most commercial software can handle static FEA simulations









Design guide informed by simulation – loads, constraints and material properties

- 1. Constrain the areas of the part which are in contact to the build plate. If supports are to be used, ensure that they are constrained both to the part and build plate.
- 2. Apply a distributed gravitational force (g=9.81 m/s²) opposite the print direction (-Z direction)
- 3. Apply a linear elastic material model to the part with the following parameters:
 - a) Young's Modulus E = 210 GPa
 - b) Poisson's ratio v = 0.4
 - c) Density $p = 4700 \text{ kg/m}^3$
- 4. Define linear static analysis with deformation and stresses as output
- 5. Run the simulation



A :=	▼ Mechanical		
	Young's Modulus	210.000 GPa	* *
Name	Poisson's Ratio	0.40	-
Stainless Steel 17-4 PH		70450 000 1 40	
Stainless Steel 17-4 PH BASF debinding properties	Shear Modulus	79150.000 MPa	-
	Density	4.700 g/cm³	×

Design guide informed by simulation – results and interpretation

- 1. Check for deformation if the loading direction and boundary conditions were correctly defined. Scaling up the deformation magnitude can assist in identifying small deformations
- 2. Plot the stresses in global x, y and z direction.
- 3. Check if the stresses are within maximum thresholds:
 - a) $X_{max} \& Y_{max} = +6$ kPa Tensile, -7kPa Compression b) $Z_{max} = +0.5$ kPa Tensile, -7 kPa Compression
- 4. If areas exceed one of the max thresholds, debinding will likely fail. Tensile and compression stress greater than their max thresholds correspond to the red and blue areas pictured on the right

E-learning modules provide further tools to understand and compensate for the outcome of this type of simulation



Ultimaker Metal Expansion Kit

Success stories



Conjunto de pinza esférica EOAT

Application summary			
Function	This end of arm tooling (EOAT) consists of two custom-shaped end effectors installed on two sliding arms. The grippers' surface envelops spherical objects from both ends, securing the product during pick-and-place operations. An auxiliary suction cup is installed on the top channel as an off-the-shelf component.		
Main benefits	 Significant weight reduction due to generative design Air channel is integrated 		
Ultimaker			
Material	Ultrafuse 17-4PH		
Cost	€ 22,95		
Print time	15 days		





Herramienta de montaje de motores diesel

Application summary			
Function	This assembly tool precisely locates diesel engine components during assembly operations. High tensile loads between internal engine components can be built-up during positioning and installation.		
Main benefits	 Severe cost reduction versus 5-axis CNC Complex shape easy to do with MFFF With the forces applied plastics is not an option 		
Ultimaker			
Material	Ultrafuse 17-4PH		
Cost	€ 32,20		
Print time	15 days		







Soporte del motor del generador

		Application summary	
FunctionThis application is a seemingly simple bracket that secures the engines powering the heavy duty power generating machines. It is ideal for additive manufacturing since it is an auxiliary component that is non-standard and only requires a low part count.		This application is a seemingly simple bracket that secures the engines powering the heavy duty power generating machines. It is ideal for additive manufacturing since it is an auxiliary component that is non-standard and only requires a low part count.	
	Main benefits	 Lead time reduction Cost reduction Weight reduction 	
		Ultimaker	
	Material	Ultrafuse 17-4PH	
Cost € 51,30		€ 51,30	
Print time 15 days			



Componente de la palanca de cambios de motocross





Accesorio de soldadura





Application summary			
P. ai	Part of a fixture for a welding machine where the load and the heat caused the polymer fixture to break.		
 More durable More heat resistant Could be designed to fit the existing system Reduced cost 			
-	Ultimaker		
	Ultrafuse 17-4PH		
	€ 29,85		
	15 days		
	P. ai		

Vacuum Gripper

Optimized for metal FFF





