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Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context

AMAZE

SUMMER SCHOOL – hosted by Politehnica Bucharest 8 – 17 July 2024

Assoc. Prof. Dr. Eng. Băilă Diana-Irinel

National University of Science and Technology POLITEHNICA Bucharest, Romania

Faculty of **Industrial Engineering and Robotics**

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European Network for Additive Manufacturing in Industrial Design for Ukrainian Context – Acronym AMAZE

INTRODUCTION IN ADDITIVE MANUFACTURING

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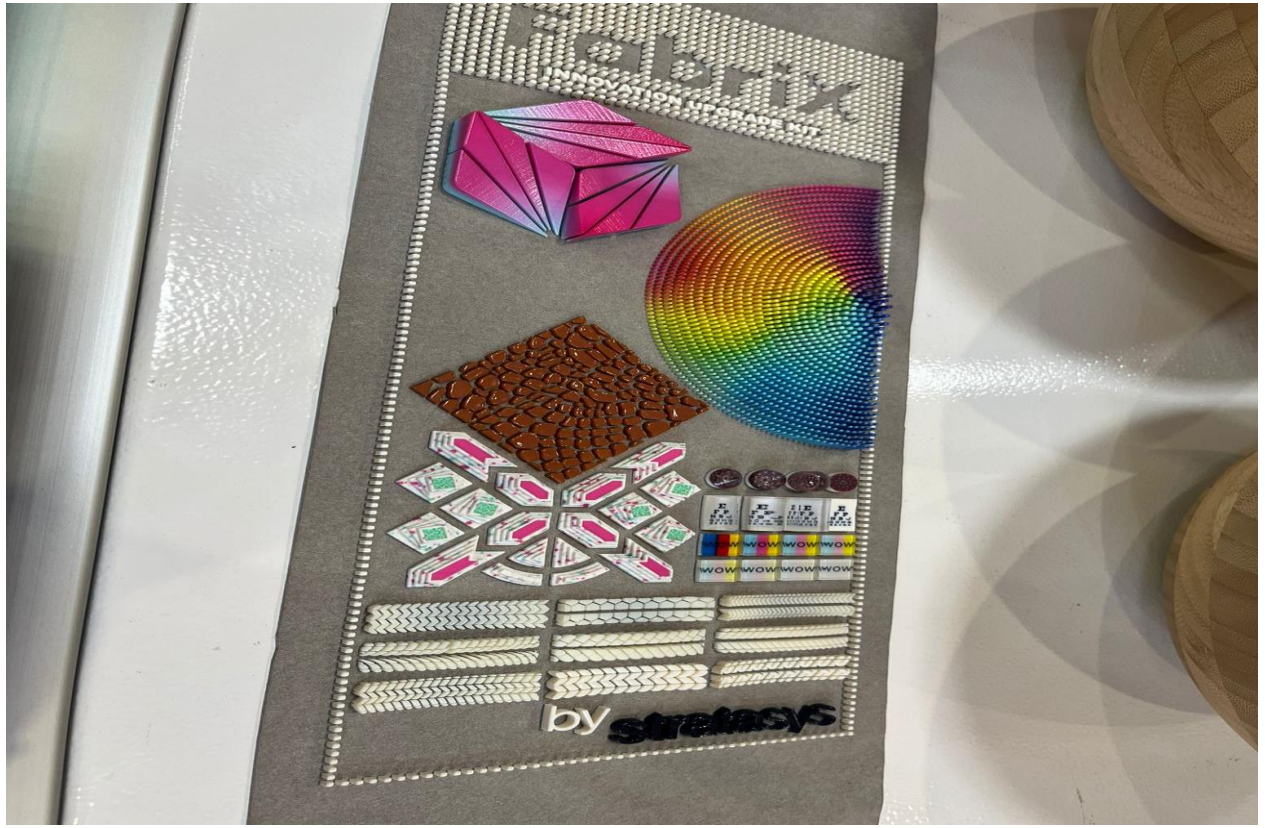
European Network for Additive Manufacturing in Industrial Design for Ukrainian Context – Acronym AMAZE

1. Additive Manufacturing in Industrial Design:

- Generalized globalization
- Strong competition
- Accelerated technological progress
- Generalization of quality systems
- The sophistication of the public (each market segment or niche wants products precisely tailored on its needs, expectations, and desires).



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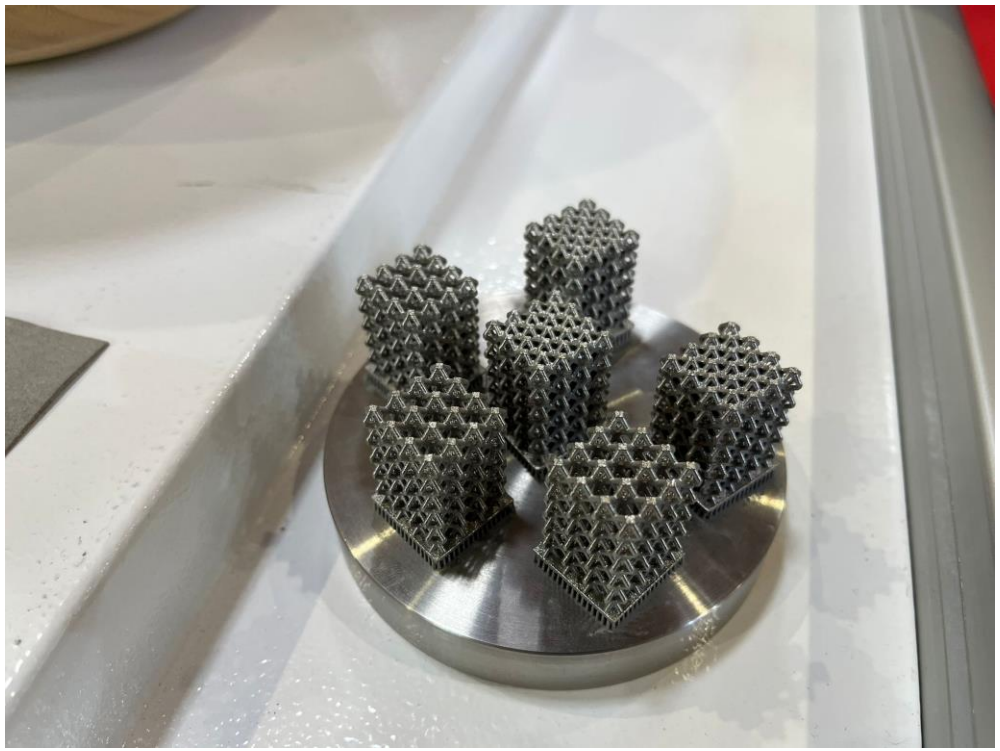
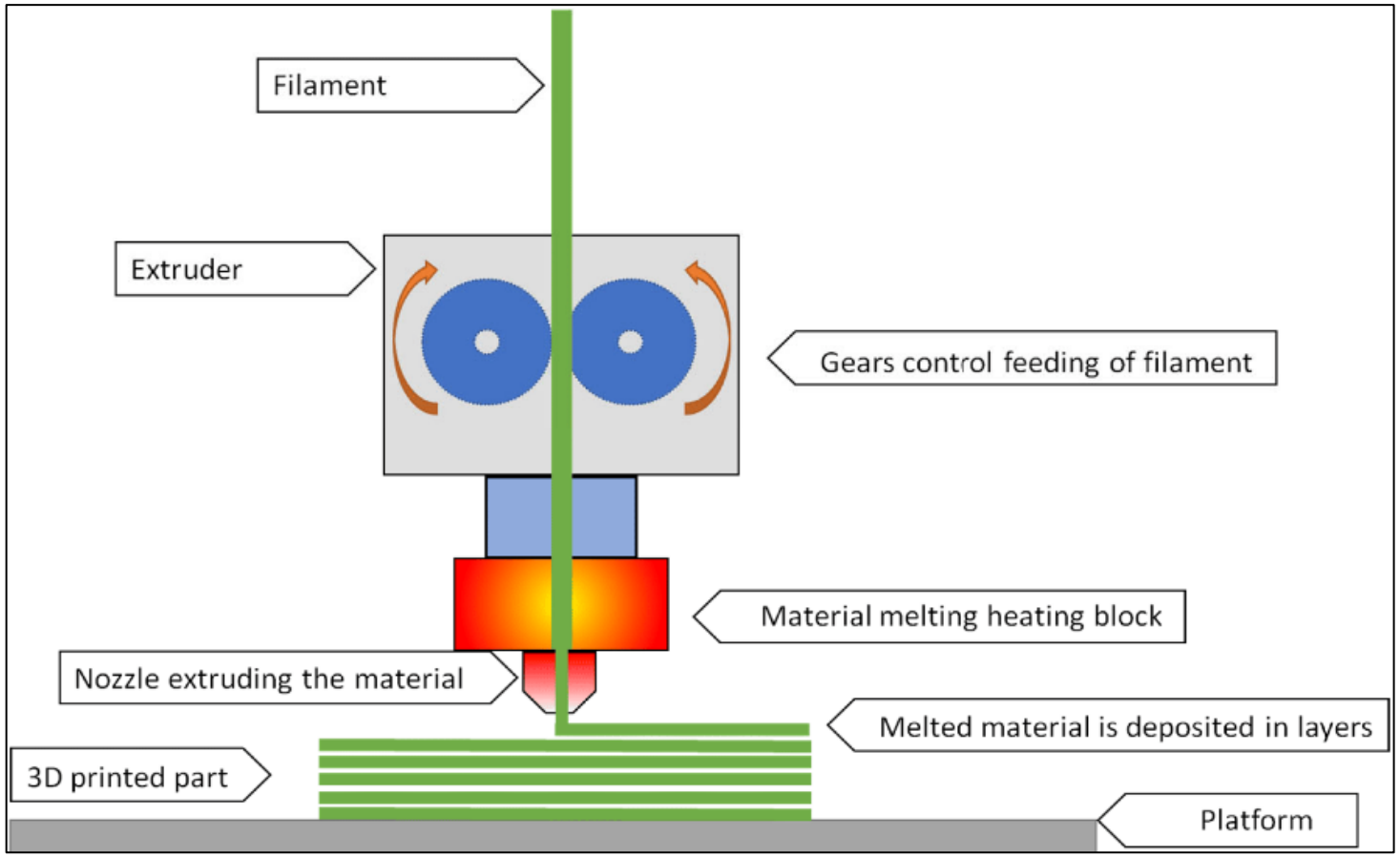
1. Additive Manufacturing in Industrial Design:



Type	Technologies	Materials
Material jetting	Drop-on-demand or continuous (single- or multi-nozzle) particle deposition	Hot-melt materials (wax, thermoplastic, metal alloy), dispersed materials (technical ceramics, metals, polymers)
Material extrusion	Fused Deposition Modeling (FDM) or Fused Filament Fabrication (FFF) and fused pellet fabrication or fused particle fabrication	Thermoplastics, eutectic metals, edible materials, rubbers, modelung clay, plasticine
	Robocasting or MIG wlding 3D printing or Direct Ink Writing (DIW) or extrusion based additive manufacturing of metals (EAM) and ceramics (EAC)	Metal-binder mixtures such as metal clay, ceramic-binder mixtures (including ceramic clay and ceramic slurries), cermet, metal matrix composite, ceramic matrix composite, metal (MIG welding)
	Additive Friction Stir Deposition (AFSD)	Metal alloys
	Composite Filament Fabrication (CFF)	Nylon or nylon reinforced with carbon, Kevlar or glass fibers
Light polymerized	Stereolithography (SLA)	Photopolymer (including preceramic polymers)
	Digital Light Processing (DLP)	Photopolymer
	Continuous liquid interface production (CLIP)	Photopolymer + thermally activated chemistry

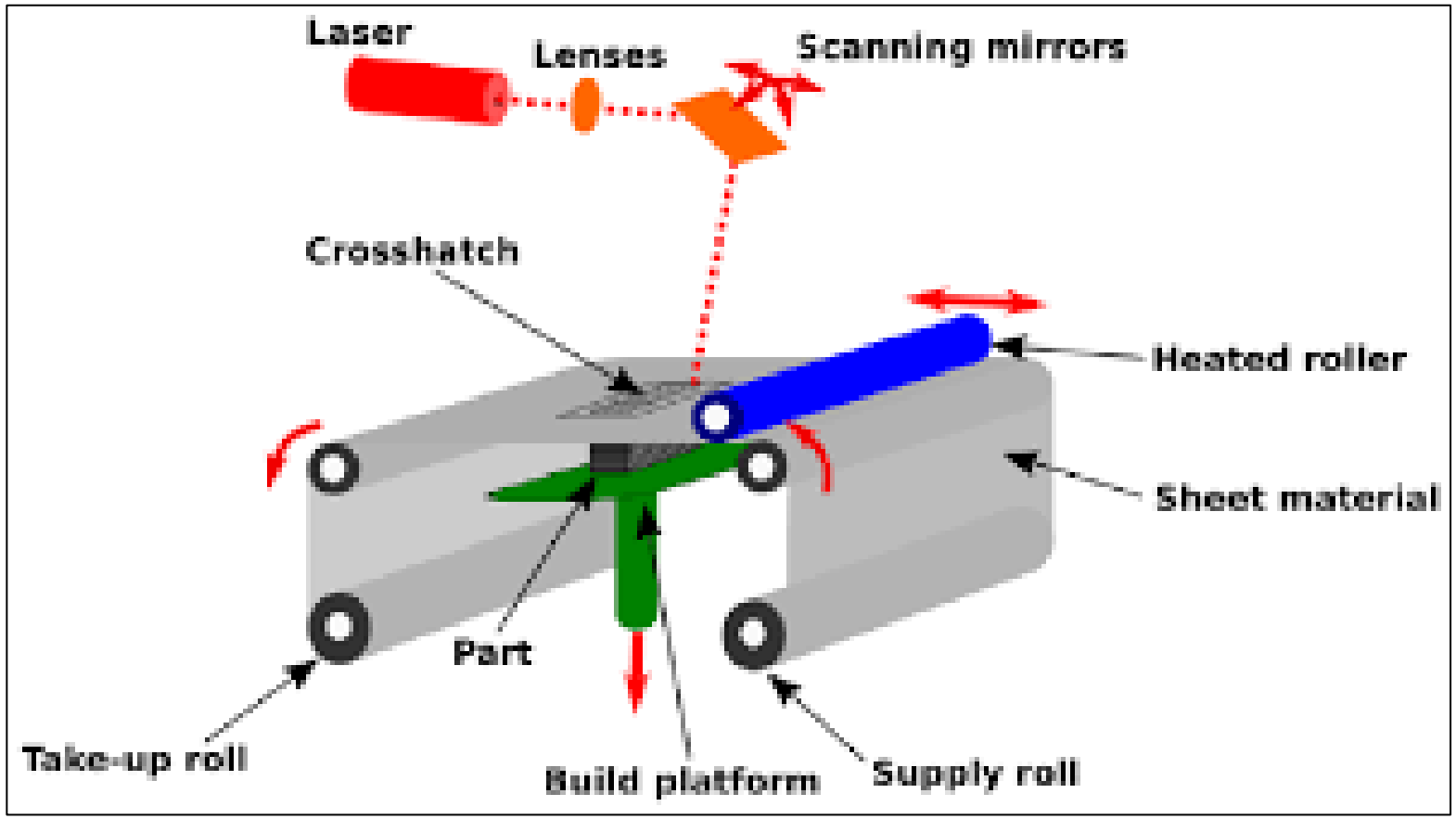
Powder Bed	Powder bed and inkjet head 3D printing (3DP)	Almost any metal alloy, powdered polymers, paster
	Electron Beam Melting (EBM)	Almost any metal alloy including titanium alloys
	Selective Laser Melting (SLM)	Titanium alloys, Co-Cr alloys, Stainless steels, aluminium
	Selective Laser Sintering (SLS)	Thermoplastics, metal powders, ceramic powders
	Selective Heat Sintering (SHS)	Thermoplastic powders
	Direct Metal Laser Sintering (DMLS)	Metal alloys
Laminated	Laminated object manufacturing (LOM)	Paper, metal foil, plastic film
	Stratoconception	
Powder fed	Laser Metal Deposition (LMD) or Directed Energy Deposition (DED)	Metal alloys
	Extreme High-speed Laser Cladding (EHLA)	Metal alloys
Wire	Electron Beam Freeform Fabrication (EBF3)	Metal alloys
	Wire-arc additive manufacturing (WAAM)	Metal alloys
Freezing	Rapid Freeze Prototyping (RFP)	Water
3D Bioprinting	3D Bioprinting	STEM cells, biopolimers



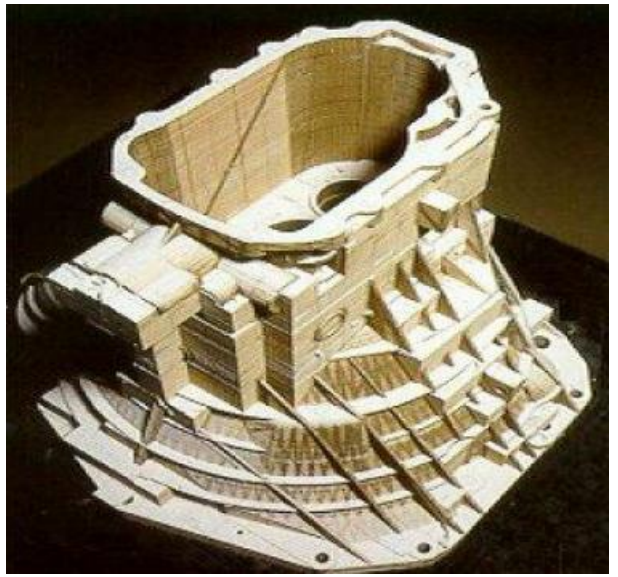
Fused Deposition Modeling (FDM) principle

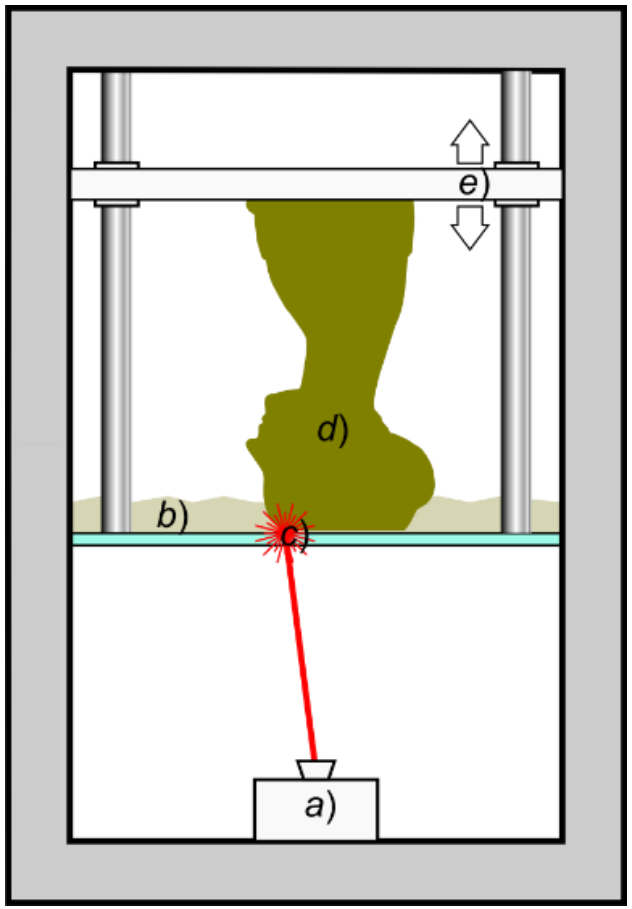
Mechanical properties between the common materials used in FDM technology, PLA, ABS and HIPS

Polymers	HIPS			ABS			PLA		
	OV	SD	SEx	OV	SD	SEx	OV	SD	SEx
MFI (g/10 min)	7.5 ± 0.20	0.16	0.11	8.76 ± 0.16	0.13	0.09	13.52 ± 0.11	0.09	0.06
Young's modulus (MPa)	112.5 ± 0.12	0.09	0.06	175 ± 0.11	0.09	0.06	47.9 ± 0.10	0.08	0.05
Yield stress (MPa)	3.44 ± 0.21	0.17	0.12	0.49 ± 0.21	0.17	0.12	0.27 ± 0.16	0.13	0.09
Glass transition temp (°C)	100.41 ± 0.16	0.13	0.09	109.76 ± 0.2	0.16	0.11	62.57 ± 0.21	0.17	0.12
Peak load (N)	80.8 ± 0.11	0.08	0.06	207 ± 0.2	0.16	0.11	282.4 ± 0.20	0.16	0.11
Peak strength (MPa)	4.21 ± 0.16	0.13	0.09	10.78 ± 0.11	0.09	0.06	14.71 ± 0.16	0.13	0.09
Peak elongation (mm)	1.9 ± 0.20	0.16	0.11	4.75 ± 0.16	0.13	0.09	5.13 ± 0.16	0.13	0.09
Percentage elongation at peak (%)	3.0 ± 0.11	0.09	0.06	6.0 ± 0.15	0.12	0.08	7.0 ± 0.10	0.08	0.05



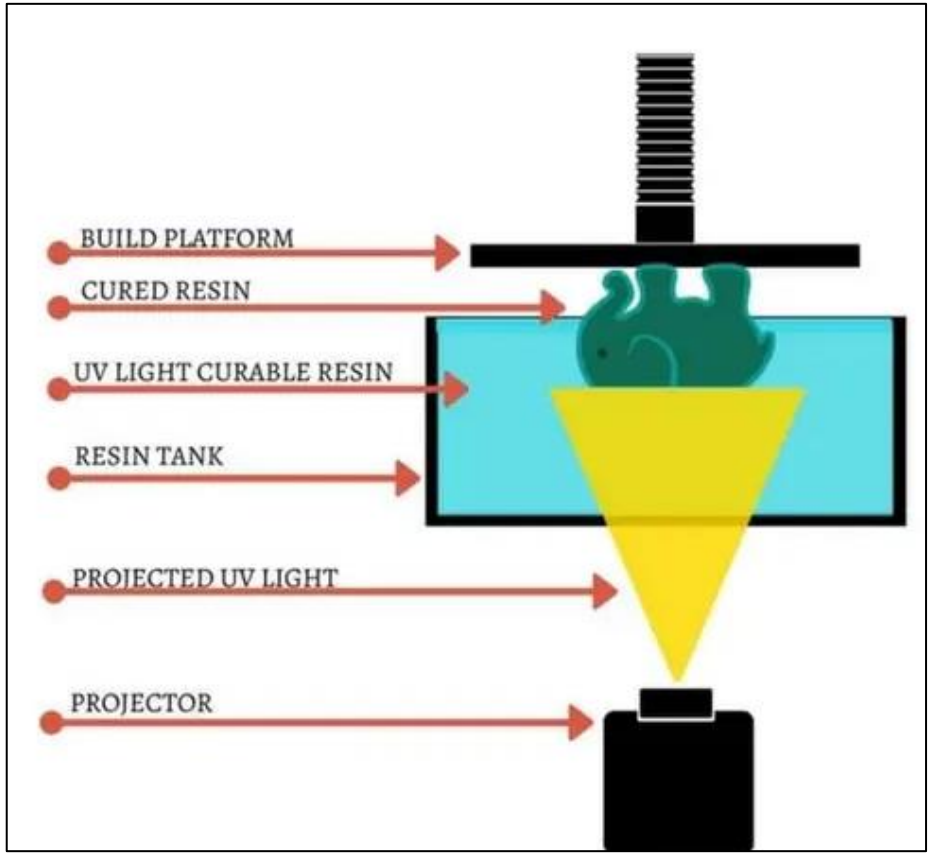
Laminated Object Manufacturing principle





Stereolithography (SLA) principle

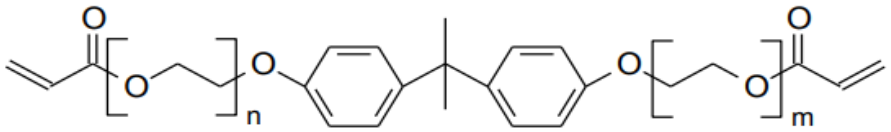
Kretzulescu Palace



Digital Light Processing (DLP)

Mechanical properties of Bisphenol A Ethoxylate Diacrylate

Bisphenol A Ethoxylate Diacrylate



n + m ~ 4

INTRODUCTION

EBECRYL 150 is an ethoxylated bisphenol A diacrylate commonly used as reactive diluent in UV/EB cure applications. EBECRYL 150 can improve the cure response, hardness, and chemical resistance of UV/EB curable coatings and inks while maintaining good adhesion, and without imparting brittleness.

PERFORMANCE HIGHLIGHTS

EBECRYL 150 is characterized by:

- High reactivity
- Moderate viscosity
- High refractive index

UV/EB curable formulated products containing EBECRYL 150 are characterized by:

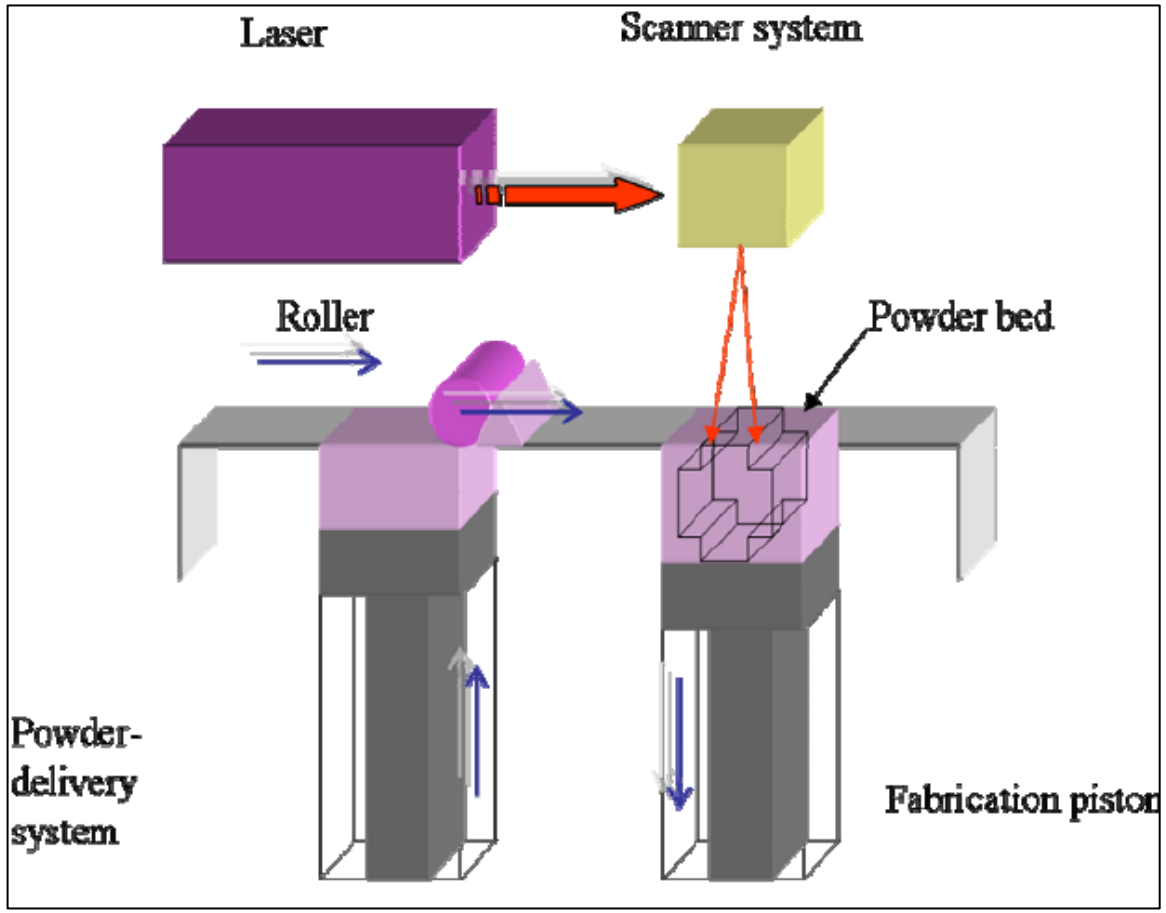
- Hardness
- Chemical resistance
- Good adhesion
- Improved wetting

The actual properties of UV/EB cured products also depend on the selection of other formulation components such as oligomers, additives and photoinitiators.

SPECIFICATIONS[1]	VALUE
Acid value, mg KOH/g, max.	5
Appearance	Clear liquid
Color, Gardner scale, max.	2
Viscosity, 25°C, cP/mPa·s	1150-1650

TYPICAL PHYSICAL PROPERTIES	
Density, g/ml at 25°C	1.14
Flash point, Setaflash, °C	>100
Functionality, theoretical	2
Refractive index (n_D at 20°C)	1.5294
Vapor pressure, mm Hg at 20°C	<0.01

TYPICAL CURED PROPERTIES[2]	
Tensile strength, psi (MPa)	6300 (43)
Elongation at break, %	9
Young's modulus, psi (MPa)	180000 (1241)
Glass transition temperature, °C[3]	41



Principle of Selective Laser Sintering technology

Industrial part with complex forms manufactured by SLS

Phenix Systems ProX DMP 100 Dental

Analogue dental implants manufactured via DMLS

SLM500 HL system

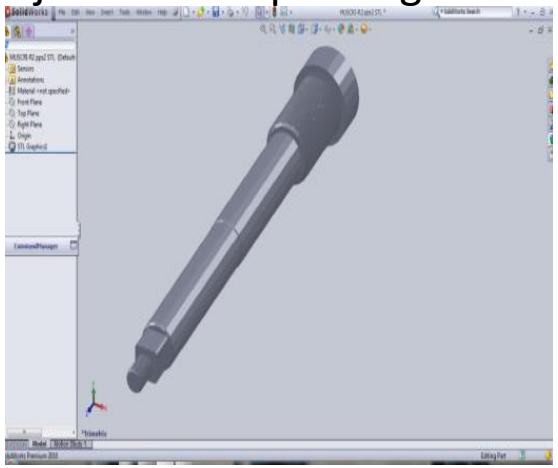
Pre-assembled micro-turbojet engine of Inconel 718 manufactured by SLM

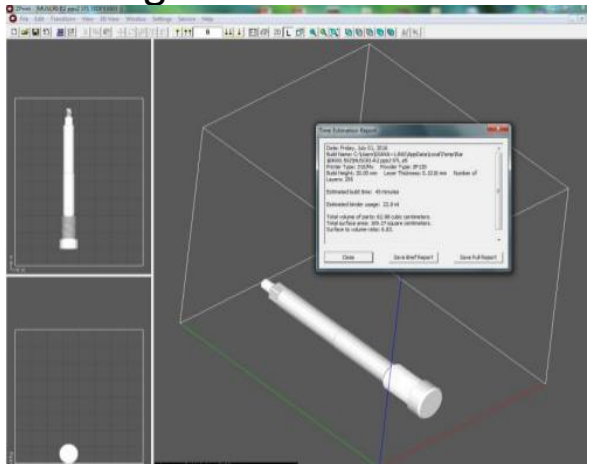
Properties of metallic materials used in SLM technology

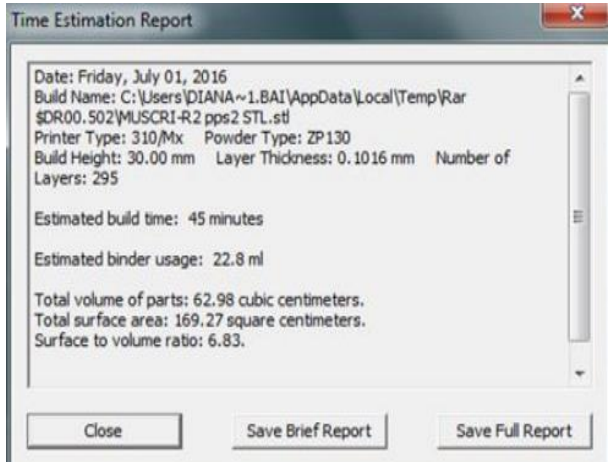
Material	Property	Value
Inconel 625	Density	8.44 g/cm^3
	Yield strength	460 MPa
	Modulus	205.8 GPa
TiAl64V	Density	4.43 g/cm^3
	Yield strength	880 MPa
	Modulus	193 GPa
Stainless steel	Density	8 g/cm^3
	Yield strength	205 MPa
	Modulus	193 GPa
AlSi10Mg	Density	2.67 g/cm^3
	Yield strength	240 MPa
	Modulus	70 GPa

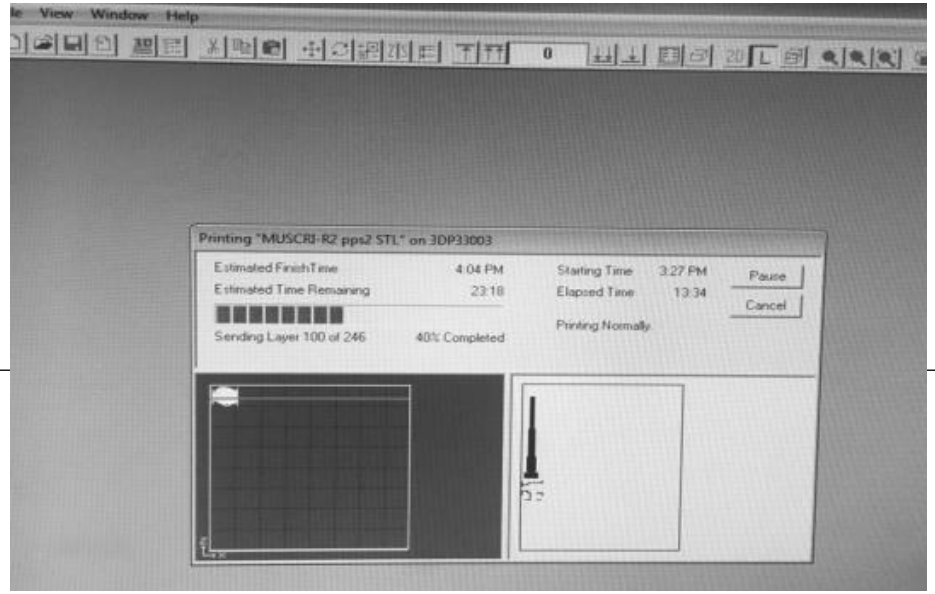
Powder bed and inkjet head 3D printing – Binder Jetting

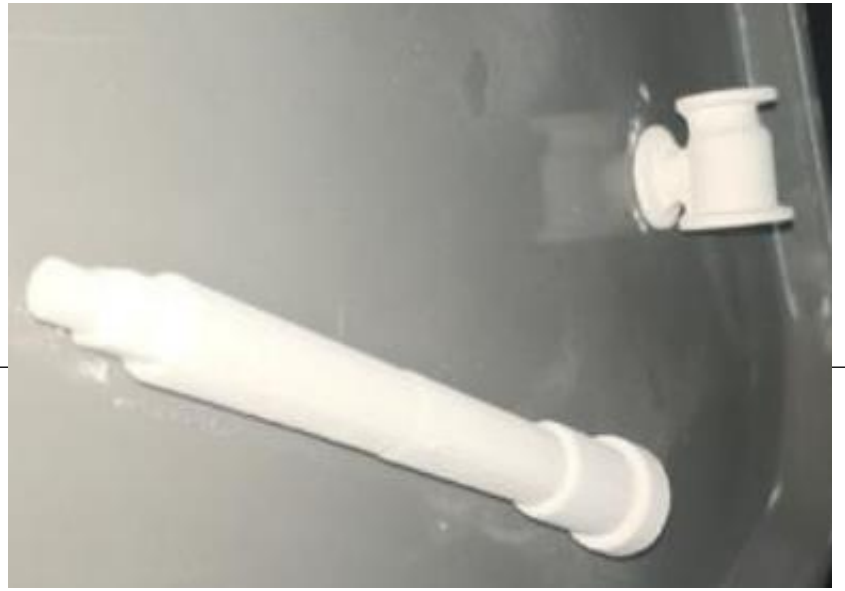
ZPrinter310 Plus system











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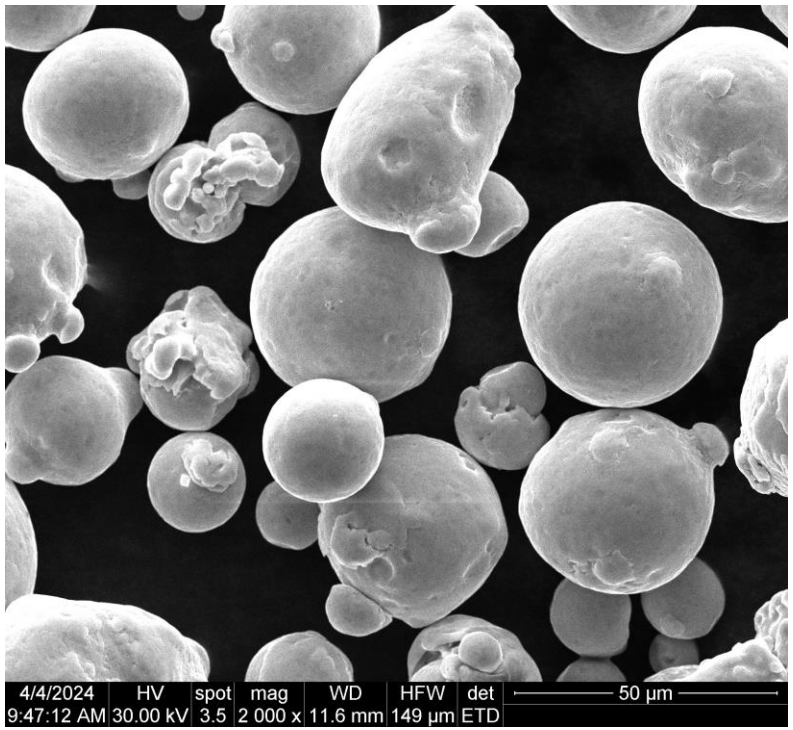
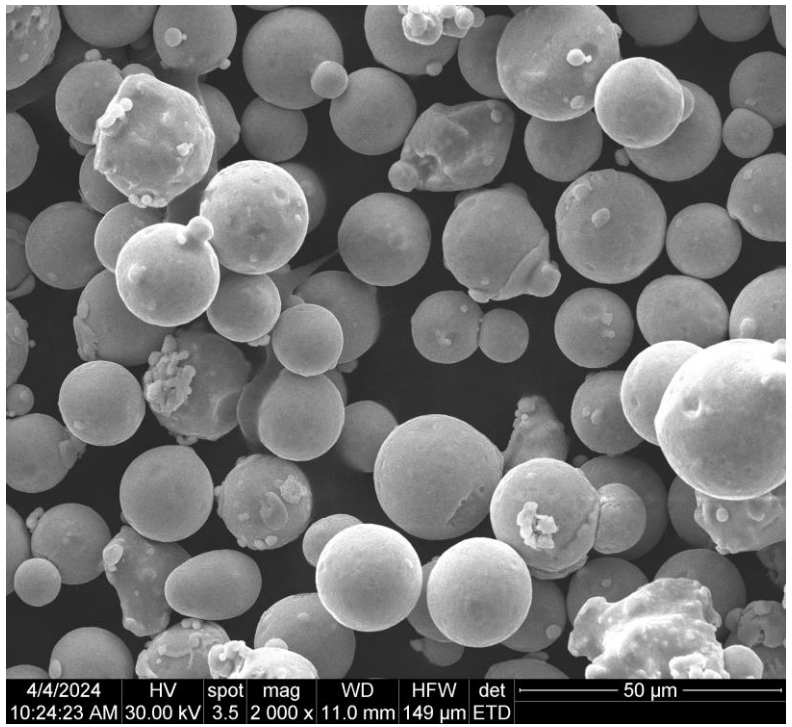
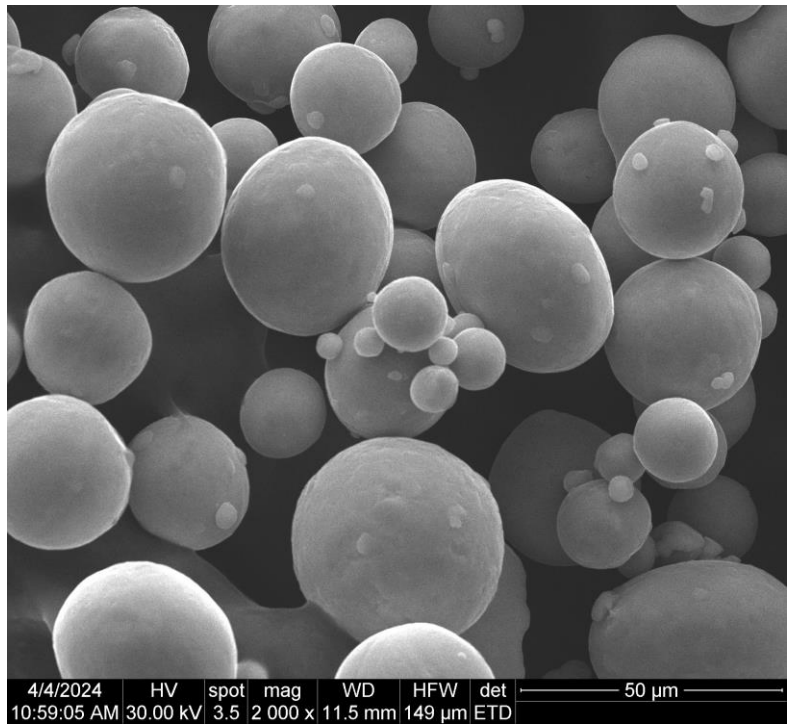
Metallic powders used in SLM (SELECTIVE LASER MELTING)



625 INCONEL

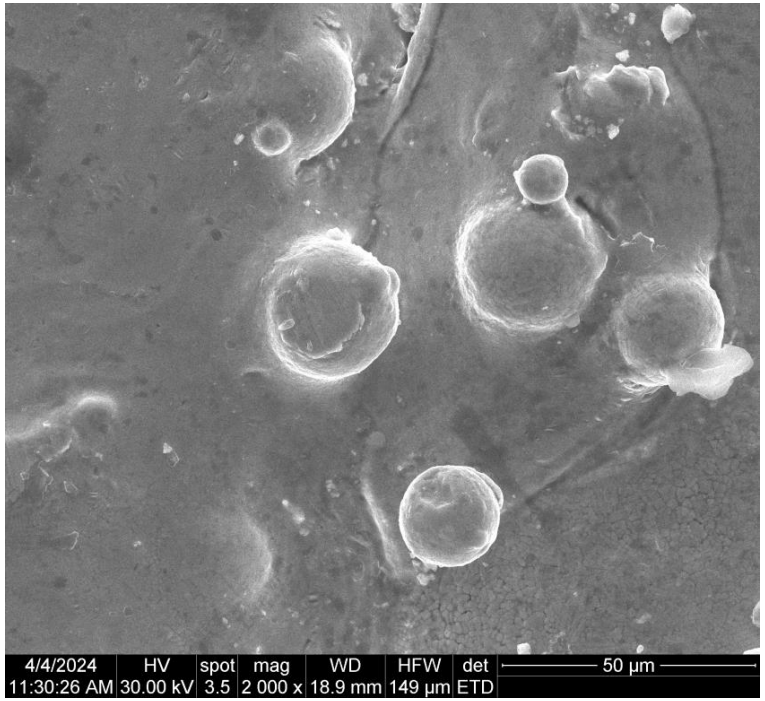


718 INCONEL

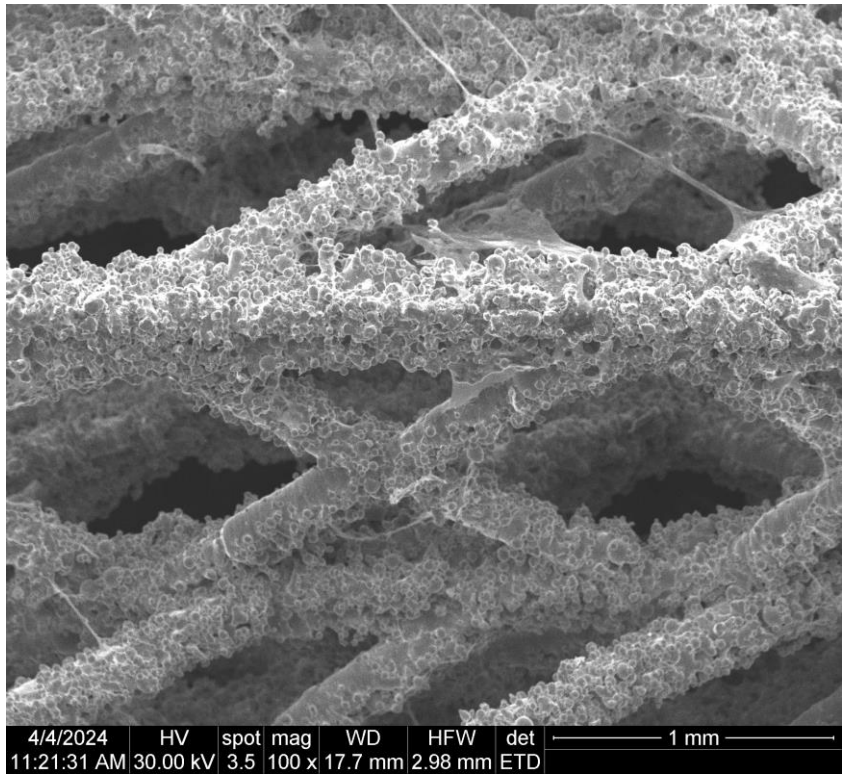


Ti6Al4V

Sintered parts used in SLM (SELECTIVE LASER MELTING)



625 INCONEL



Ti6Al4V

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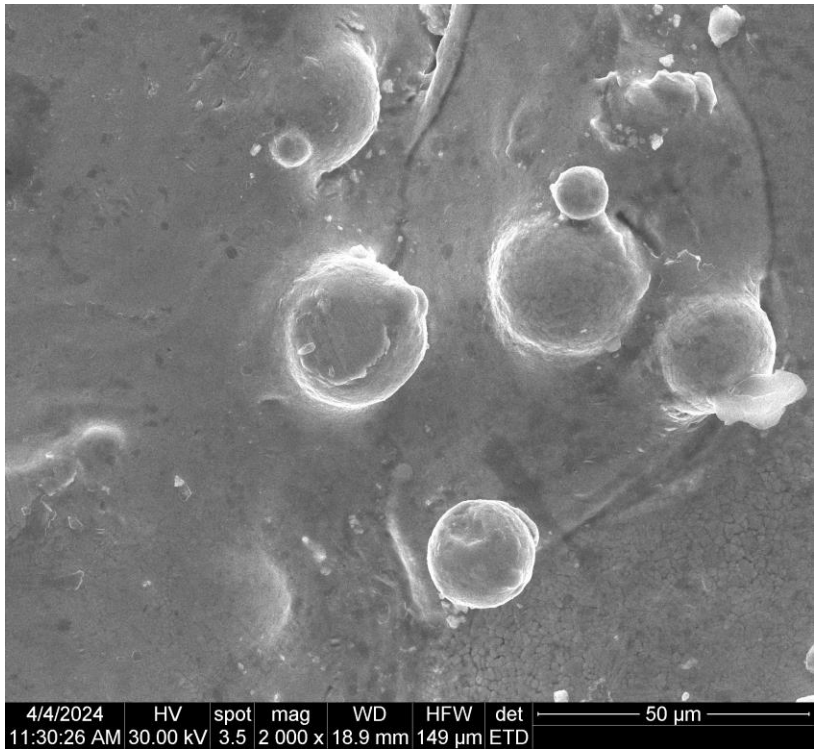

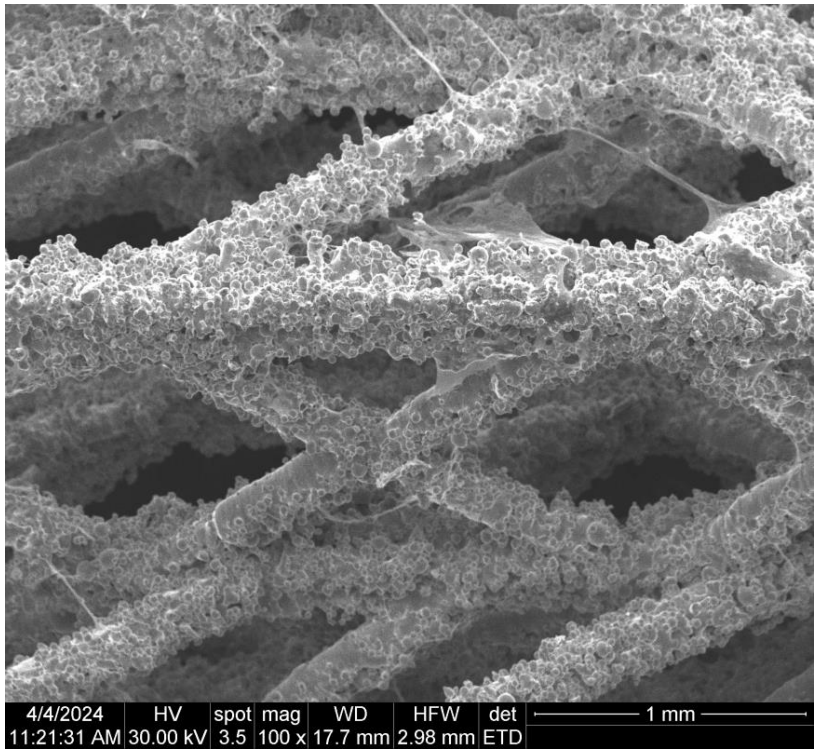

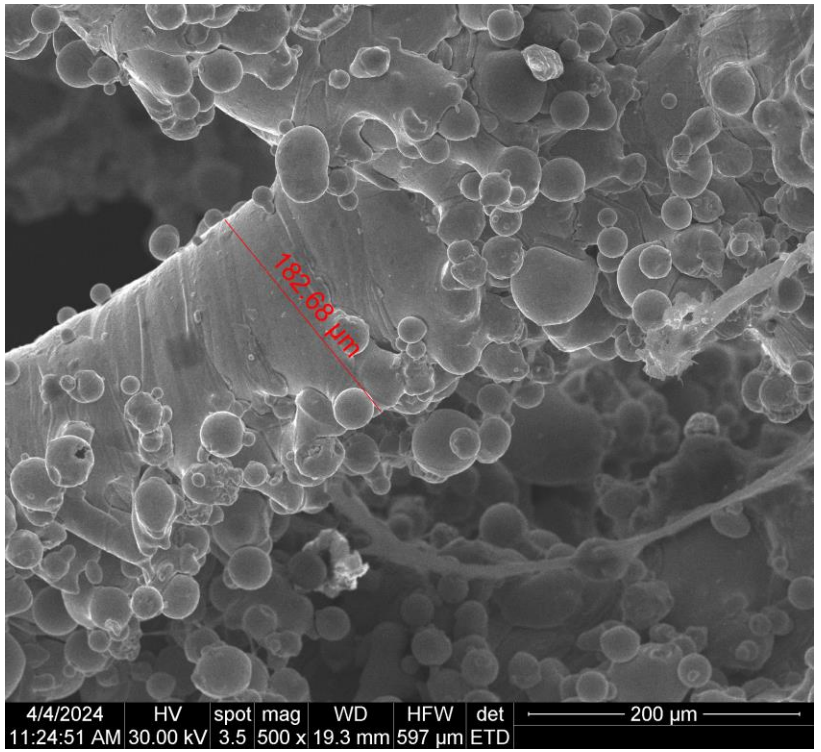

625 INCONEL

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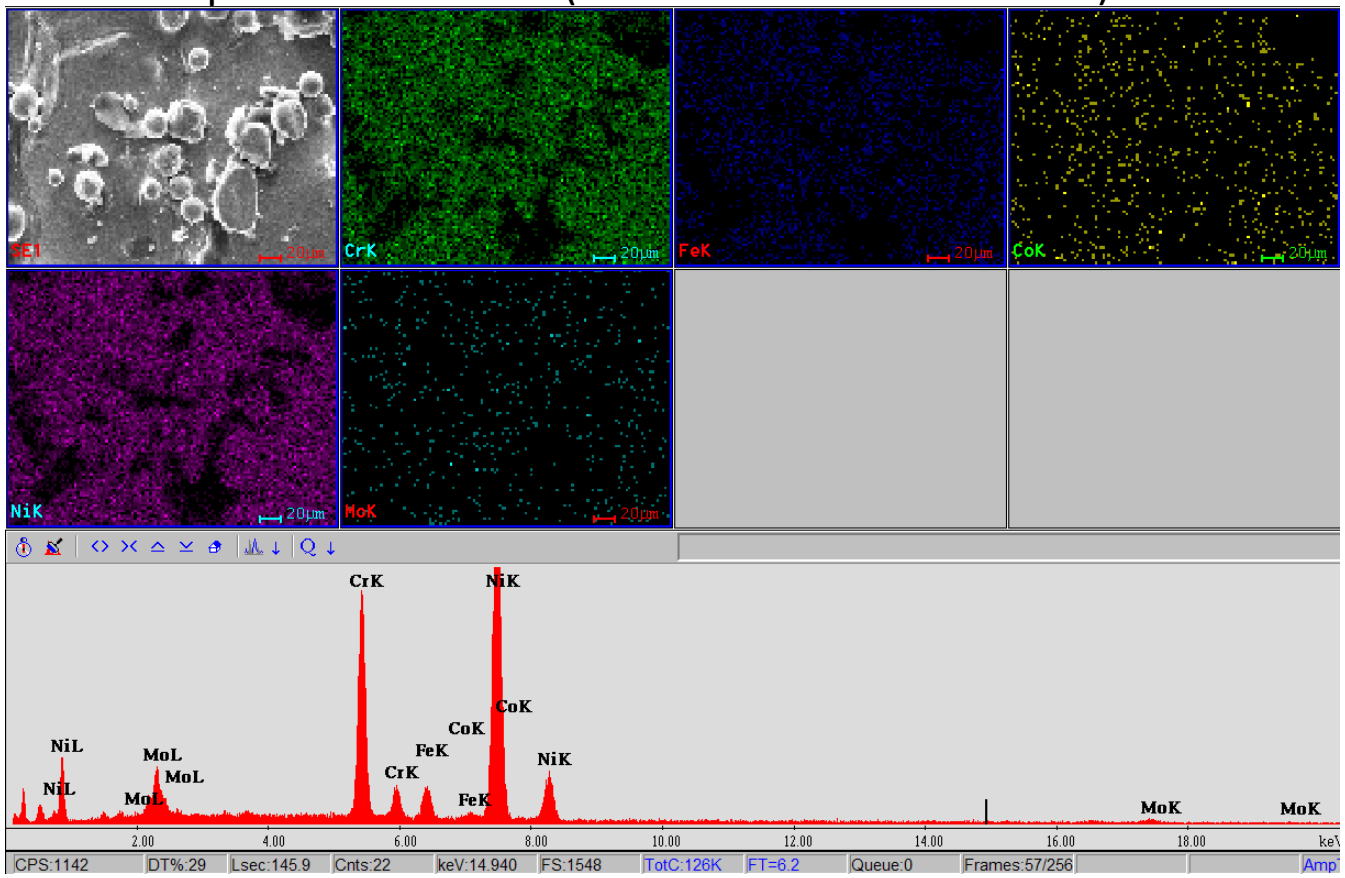

625 INCONEL

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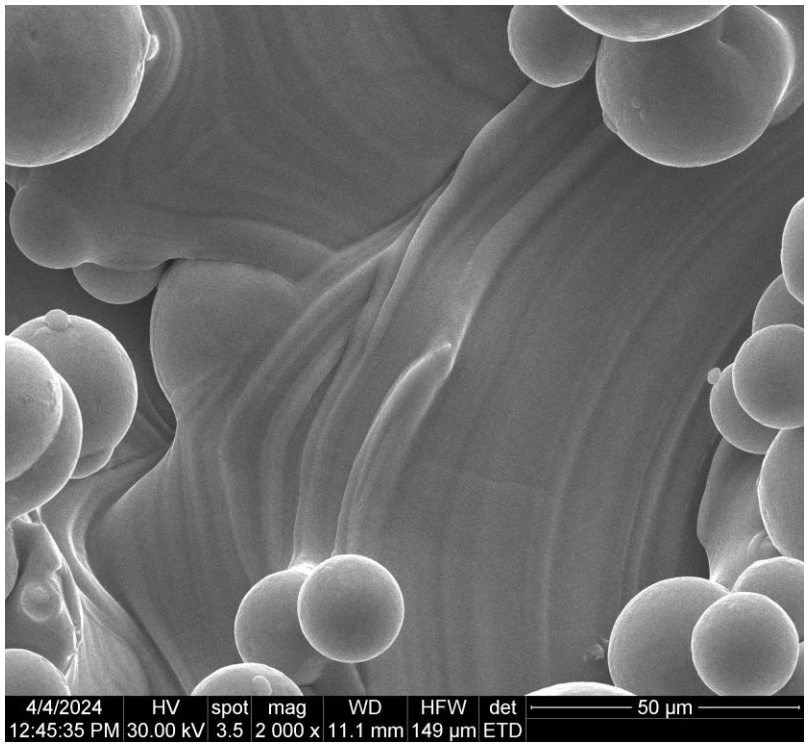
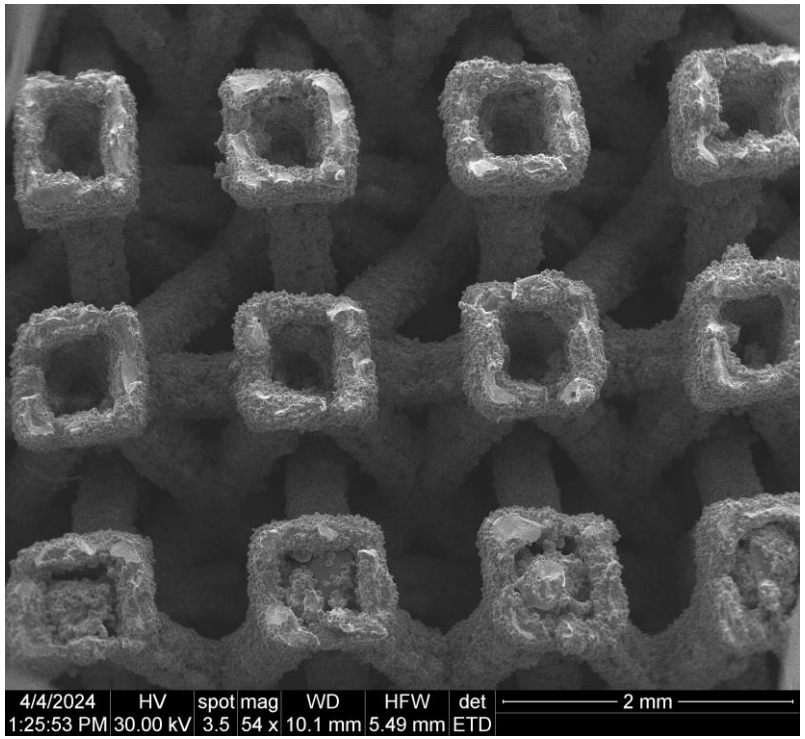
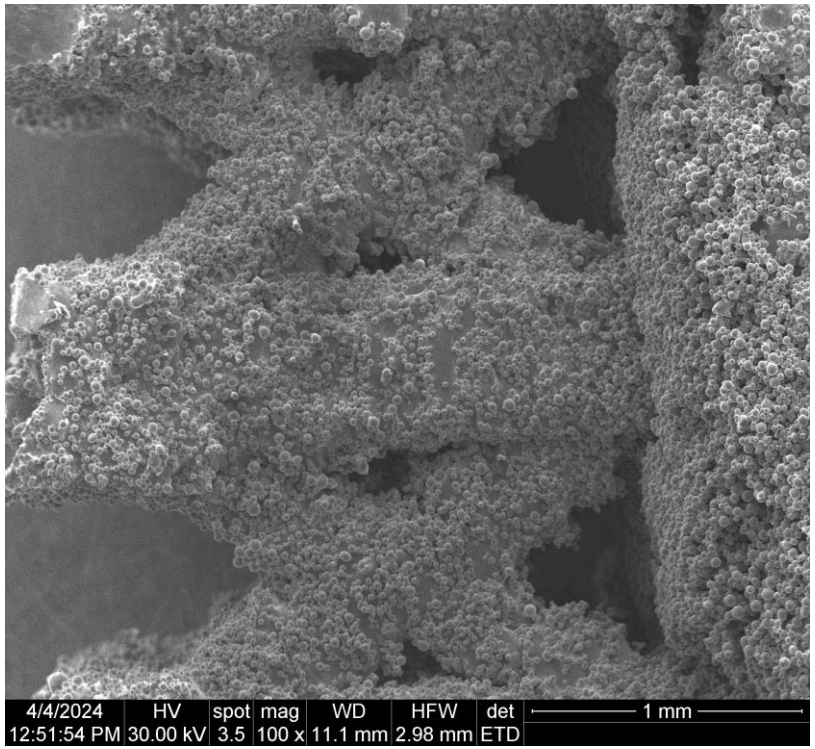
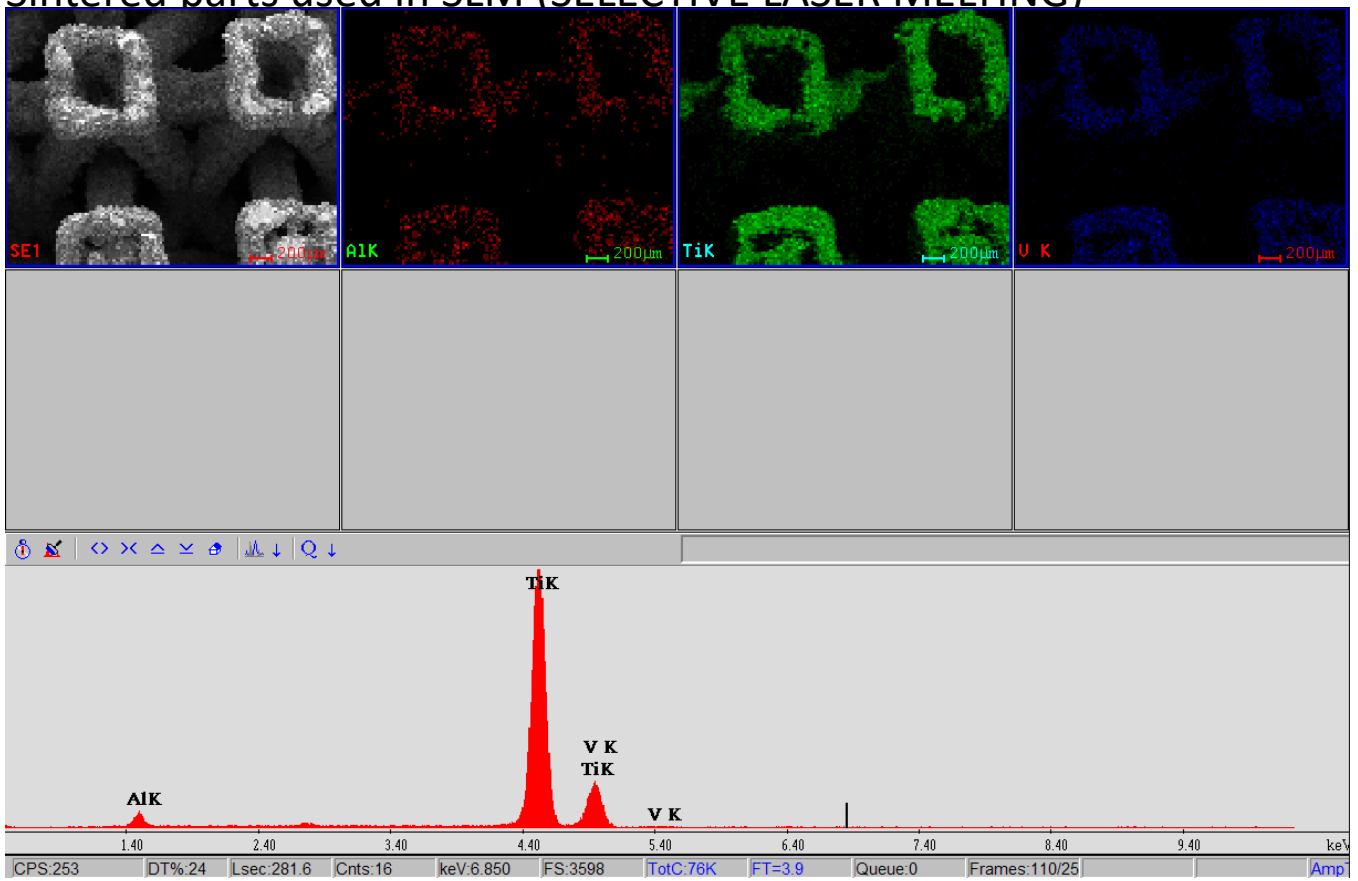






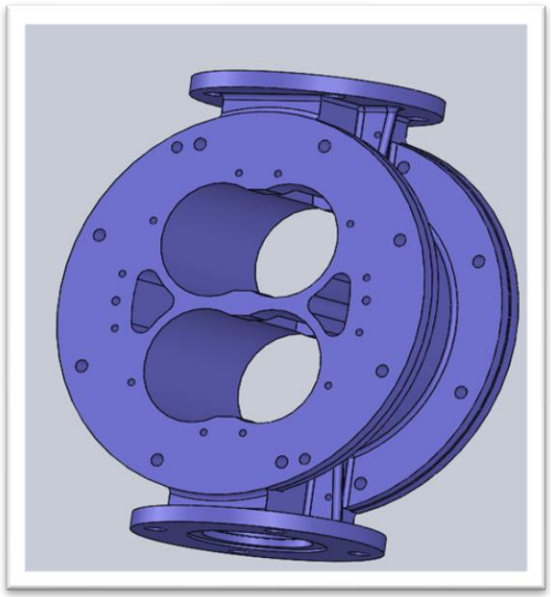
Ti6Al4V

Sintered parts used in SLM (SELECTIVE LASER MELTING)



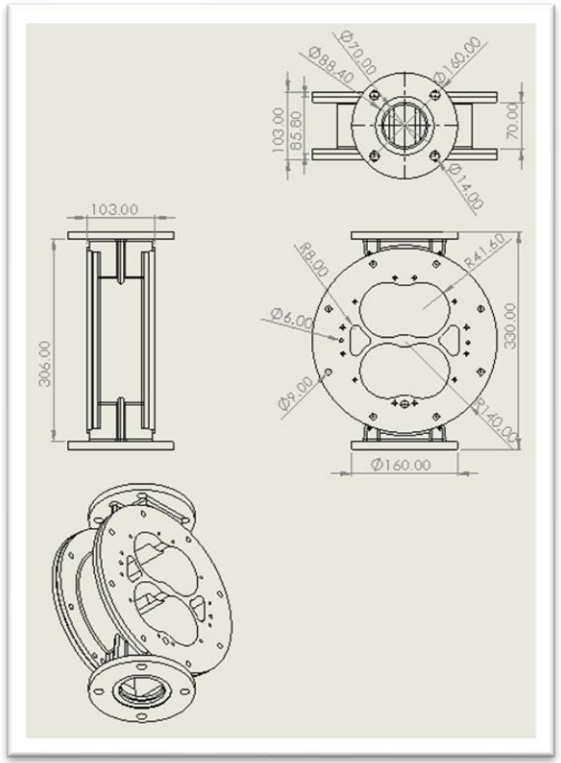
Ti6Al4V

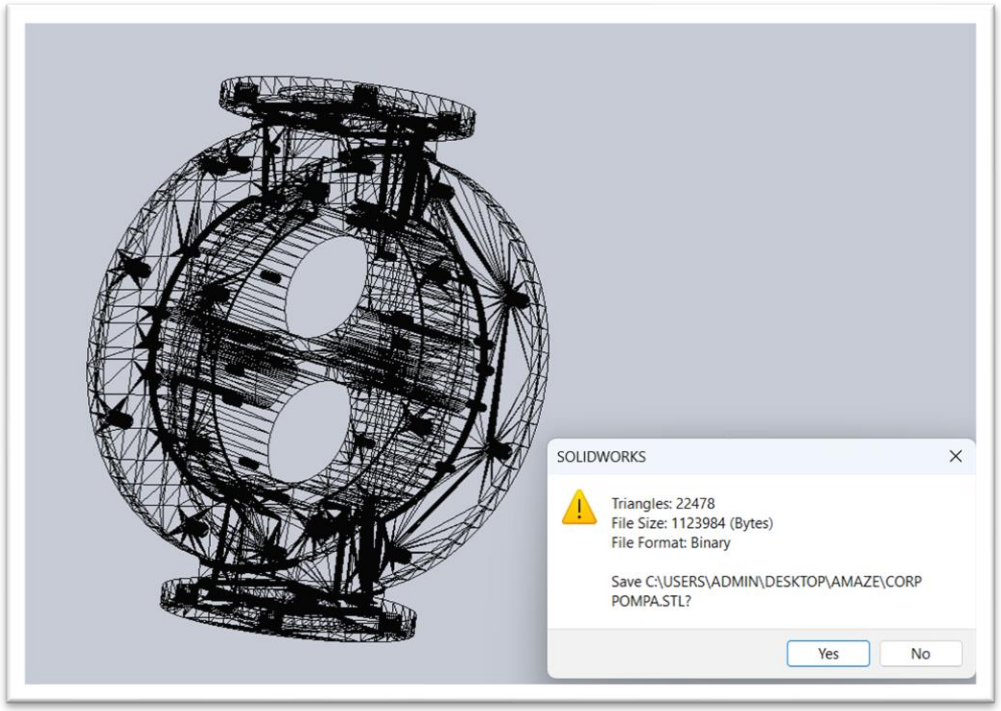
Part 1 – Hydraulic pump body



Hydraulic pump body – SLDPRT

Ti6Al4V





Hydraulic pomp body meshing – STL. file

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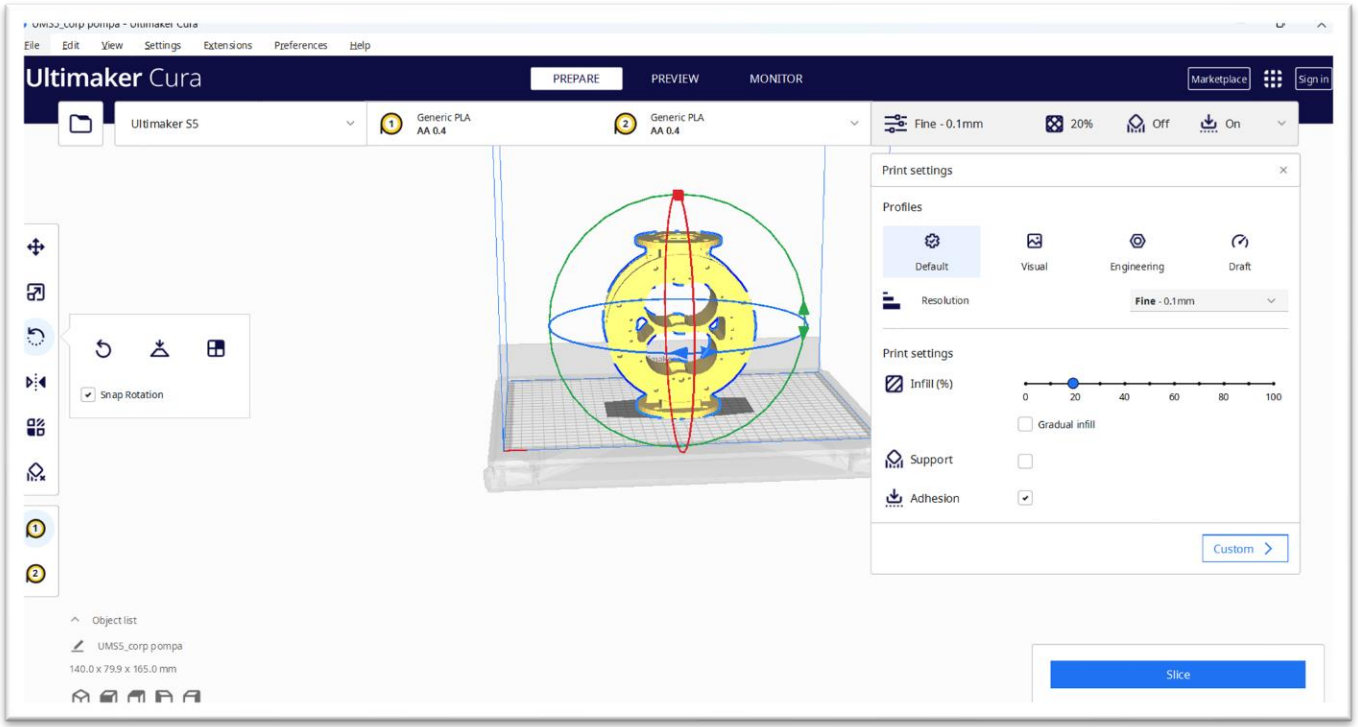

Open Ultimaker Cura software and introduce the STL. file of part

Table 1. The mechanical properties of PLA (Polylactic Acid)

Properties	Values	Units
Density	1.25	g/cm3
Poisson's Ratio	0.36	-
Shear Modulus G	2.4	GPa
Melting Temperature	173	°C
Glass transition temperature	60	°C
Thermal Conductivity	0.13	W/m-K
Extruded Temperature	160-220	°C
Heat Resistance	110	°C
Young's modulus	3.5	GPa
Tensile Strength	61.5	MPa
Compressive Strength	93.8	MPa
Elongation at Break	6	%
Flexural strength	88.8	MPa
Hardness Shore D	85	A
Impact Strength	30.8	kJ/m2
Yield Strength	60	MPa
Standard Tolerance	+/-0.05	mm
Biodegradable	yes	-

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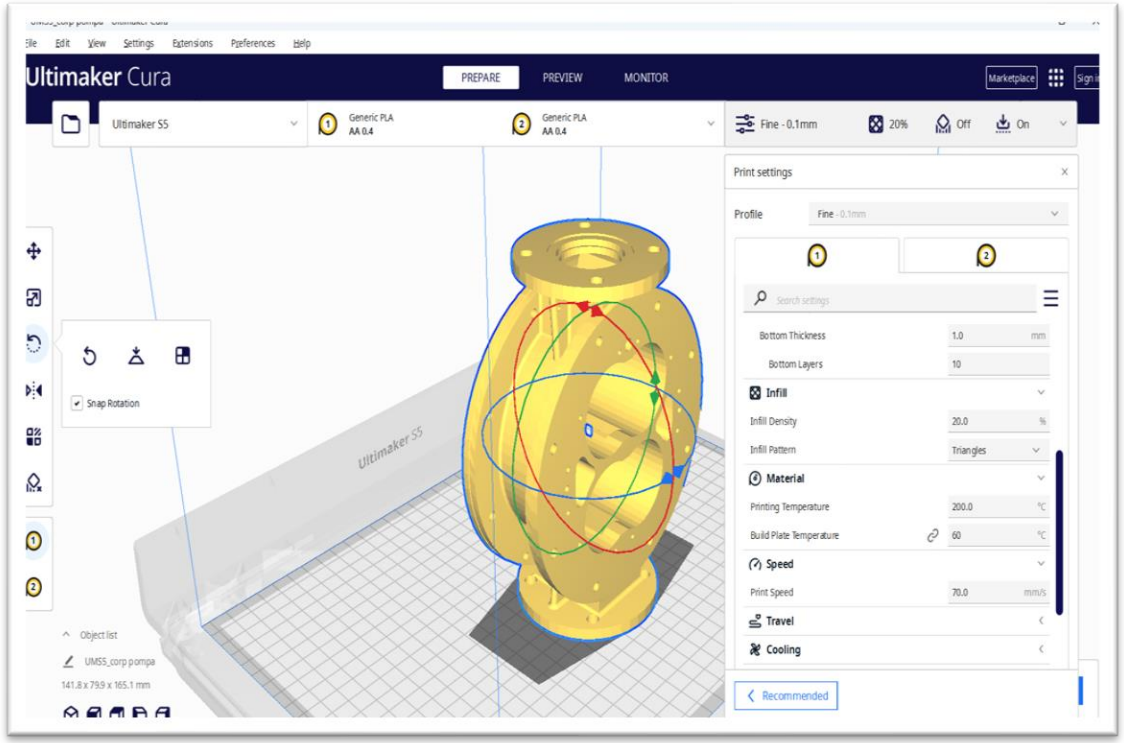
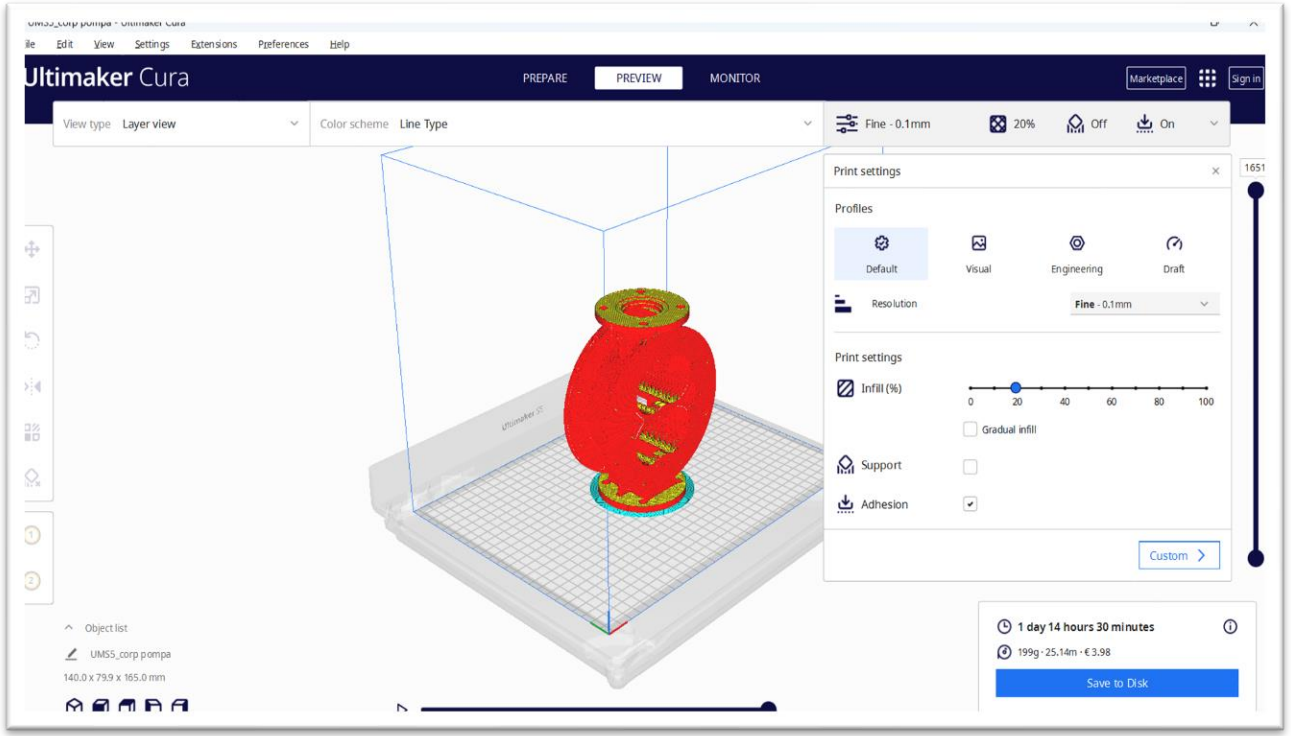


Manufacturing parameters for custom Additive Manufacturing without supports



Recommended manufacturing parameters for the part by the software

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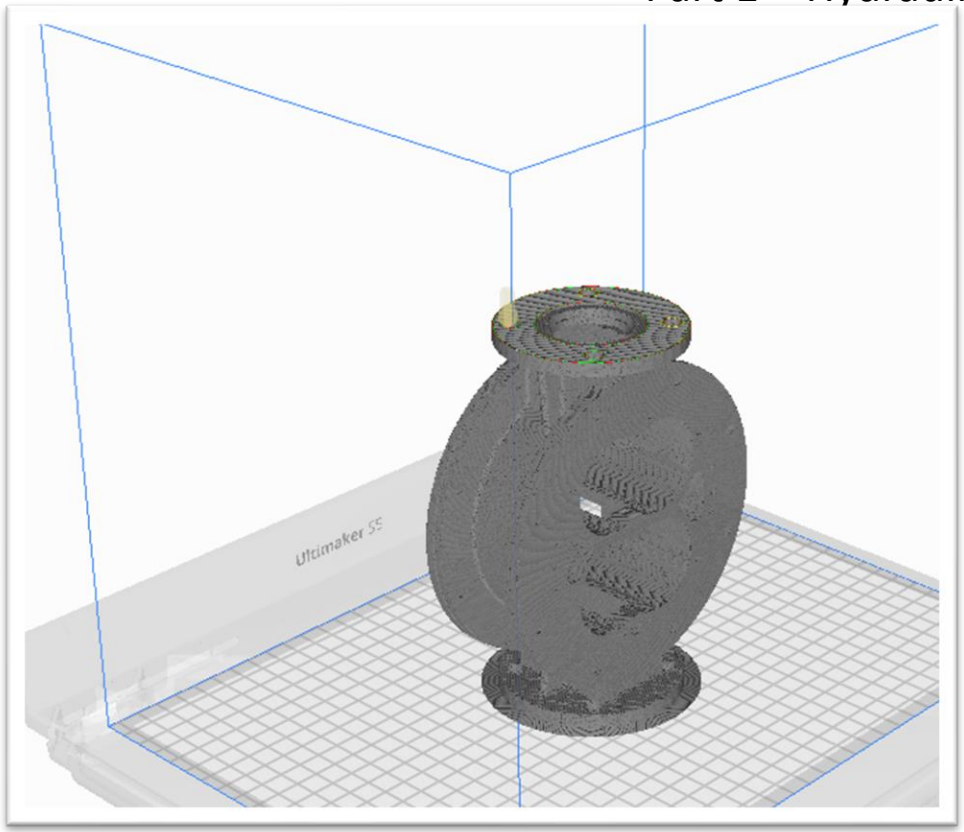
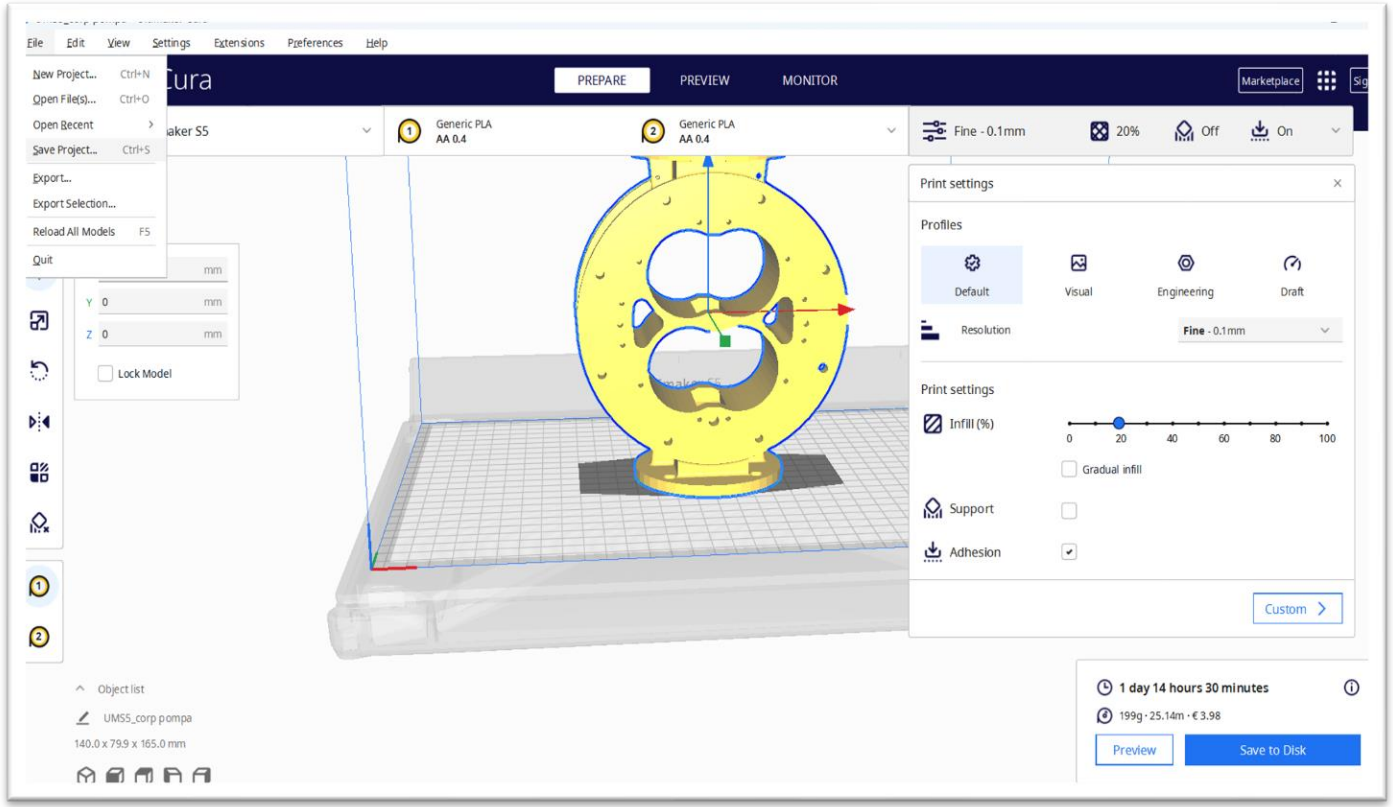


Preview the manufacturing 3D Printing process



Save Project

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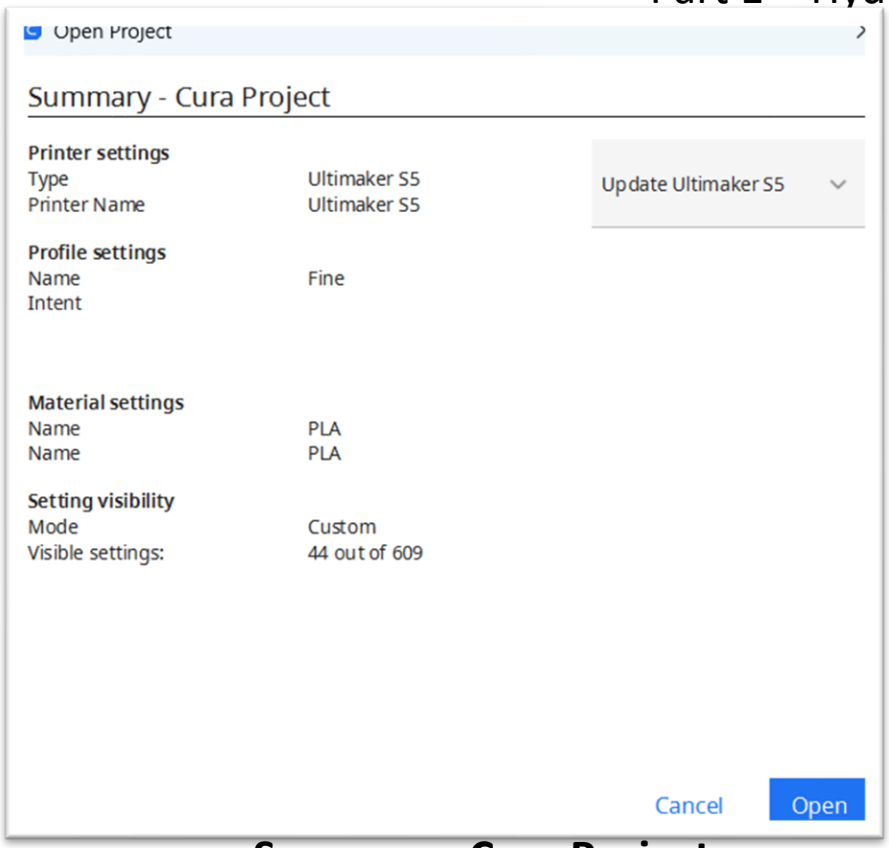
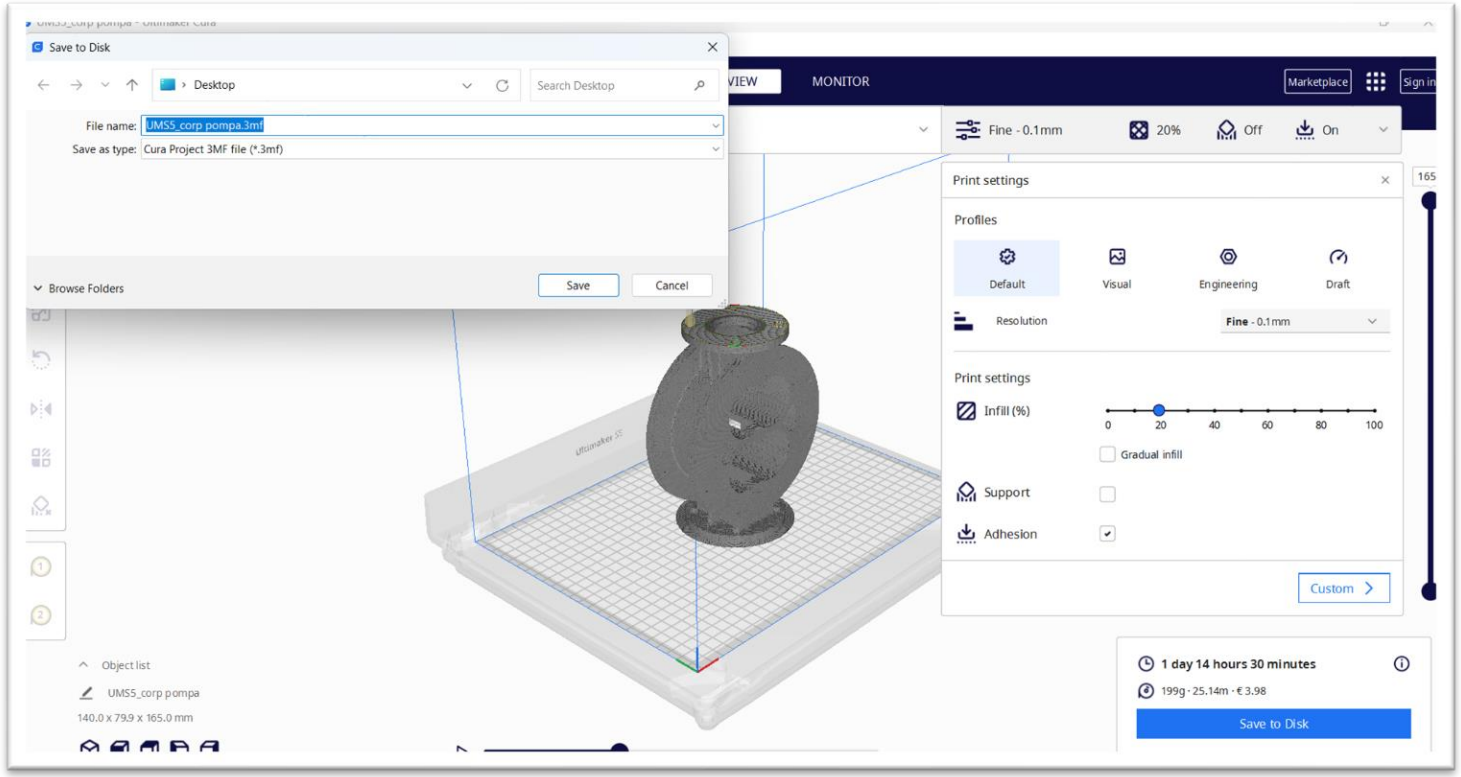


Summary- Cura Project



Save Project as 3mf. file

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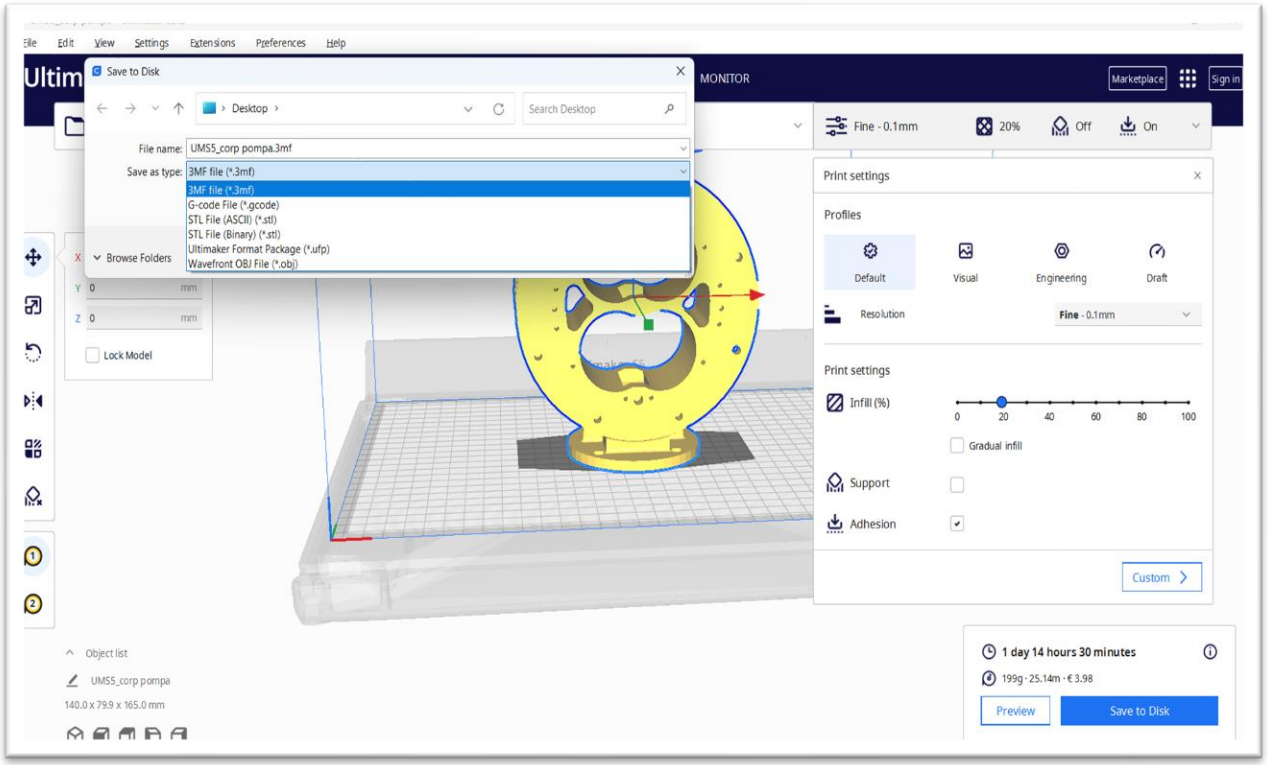
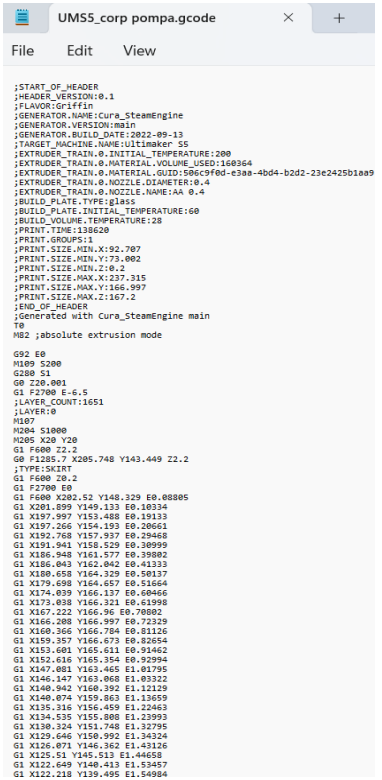
Part 1 – Hydraulic pump body





Different extension for file export

G-code file for hydraulic pomp body

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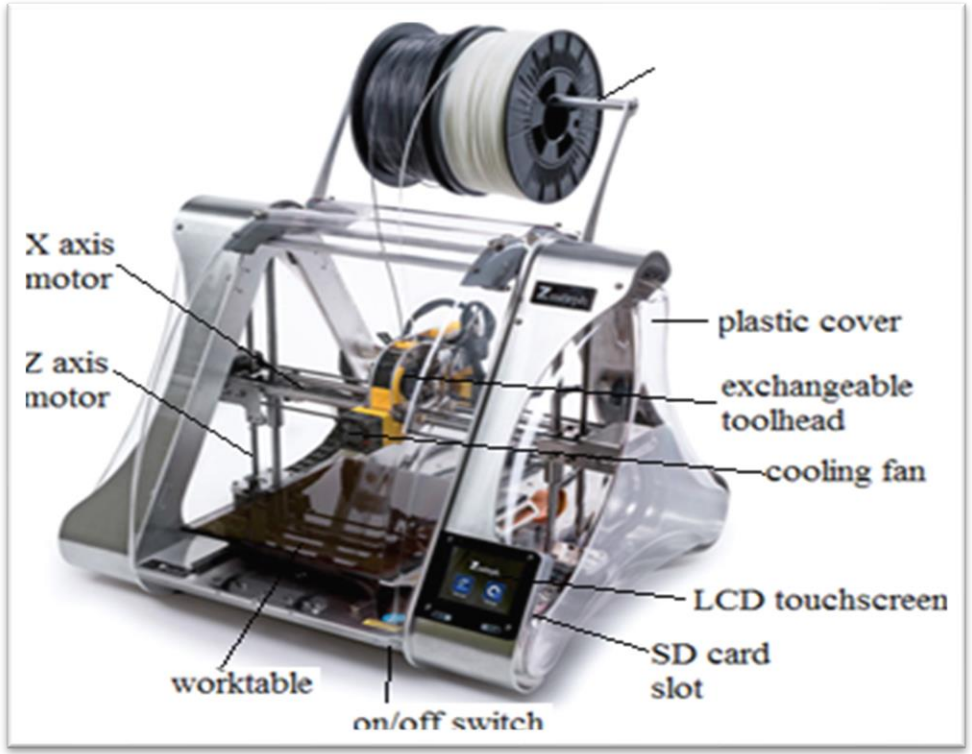
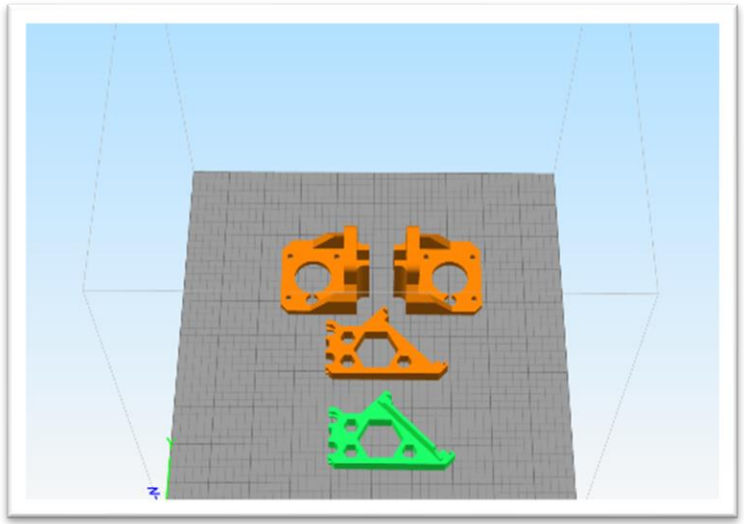
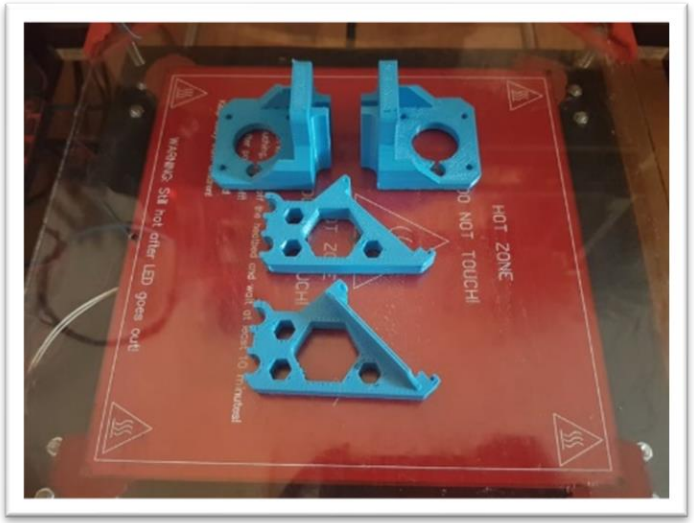
Part 2 - Electronic components used for the manufacture of 3D hybrid printer, type DIY (do it yourself)







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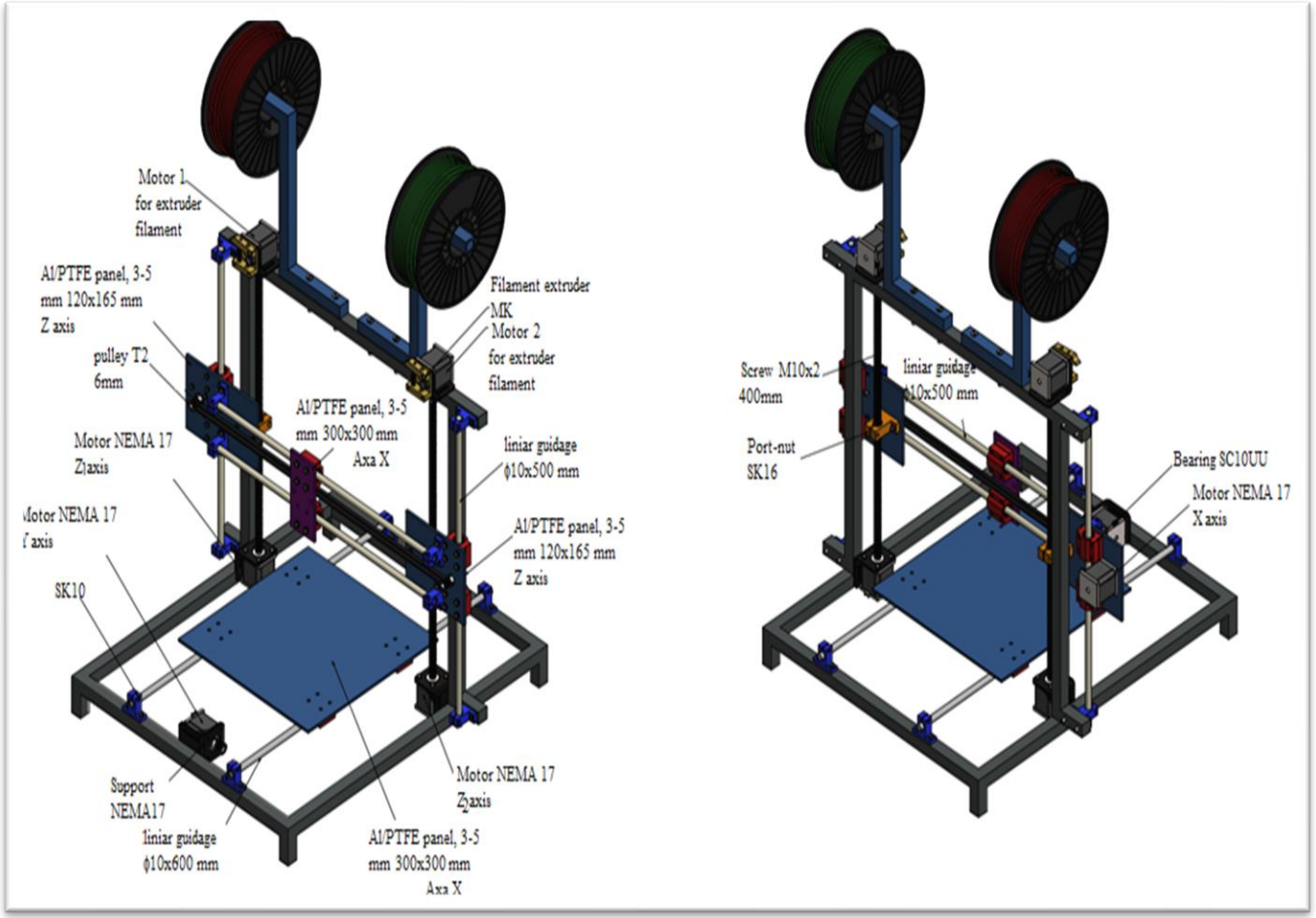
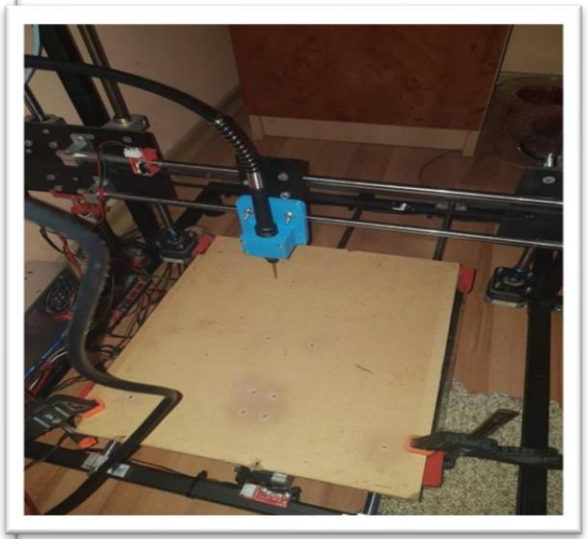
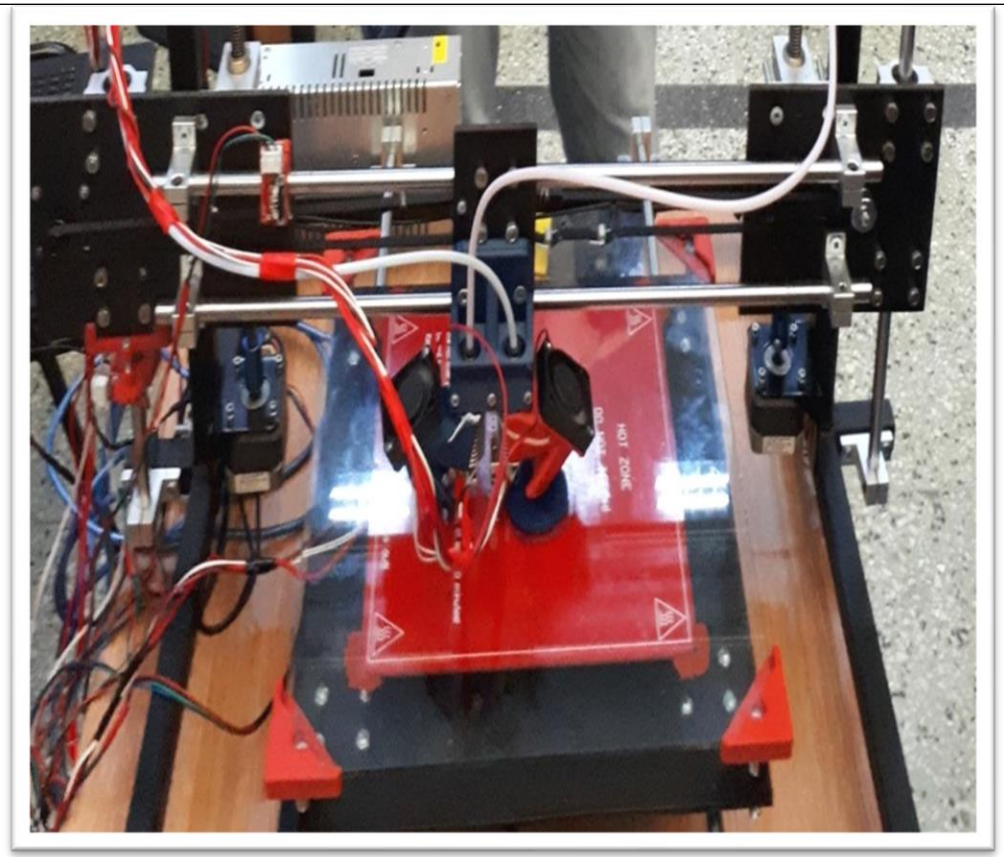


2. Electronic components used for the manufacture of 3D hybrid printer, type DIY (do it yourself)

CNC head of 3D hybrid printer



CNC drilling on the 3D hybrid printer.

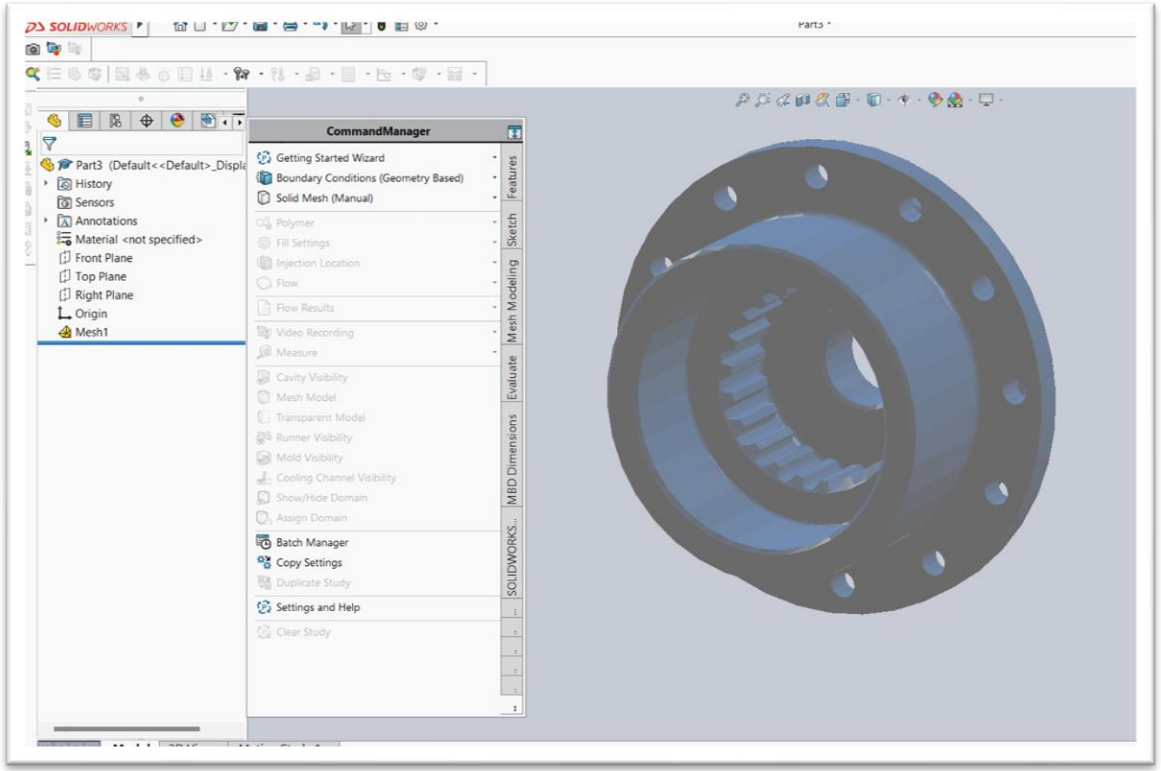


FDM extruder on the 3D hybrid printer

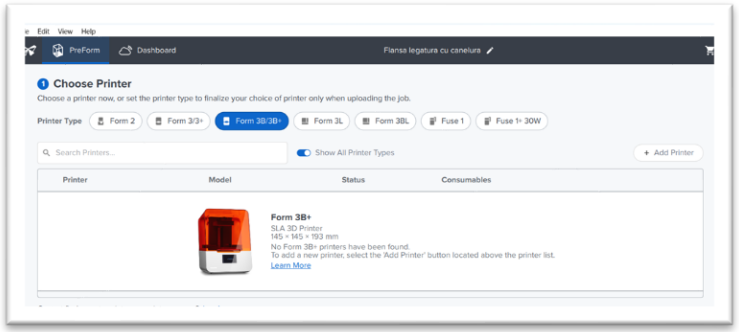
2. Electronic components used for the manufacture of 3D hybrid printer, type DIY (do it yourself)

CNC head of 3D hybrid printer

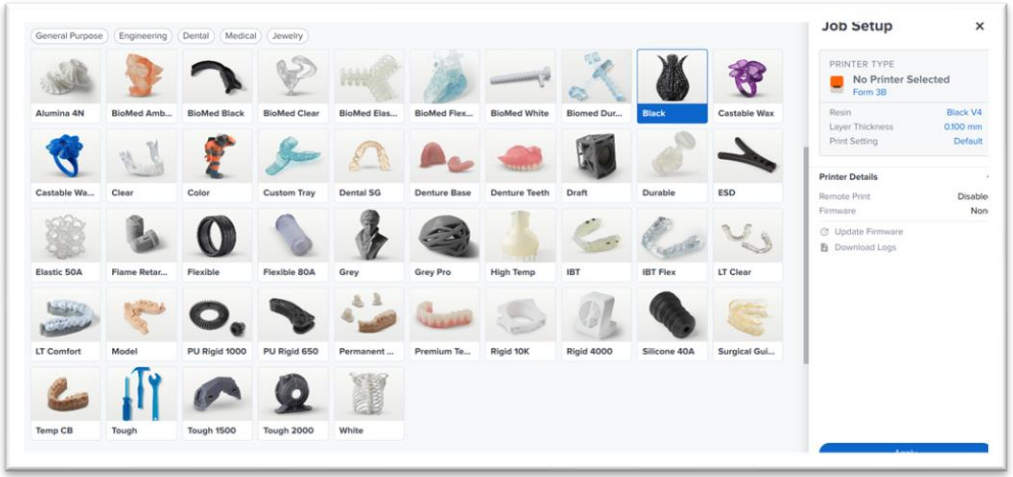
Part 3: Flange.stl file



flange stl. file for printing



Software PreForm, Form 3B+ printer chosen



Photopolymerisable resin and layer thickness chosen

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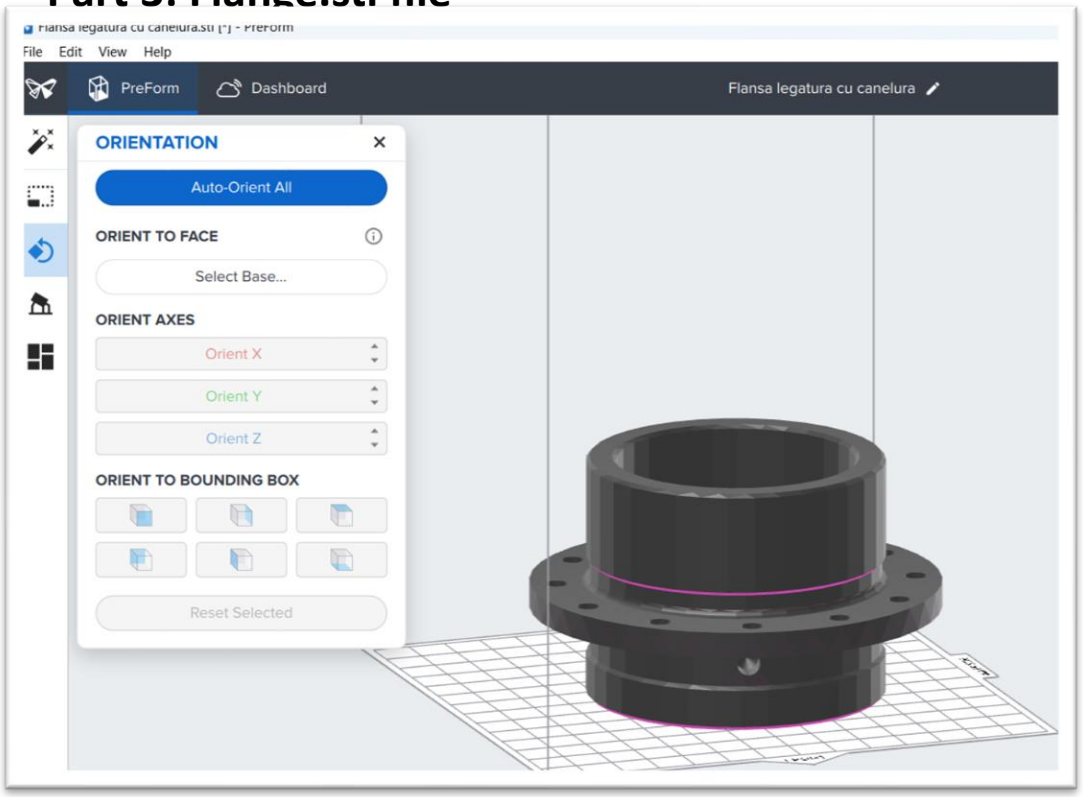
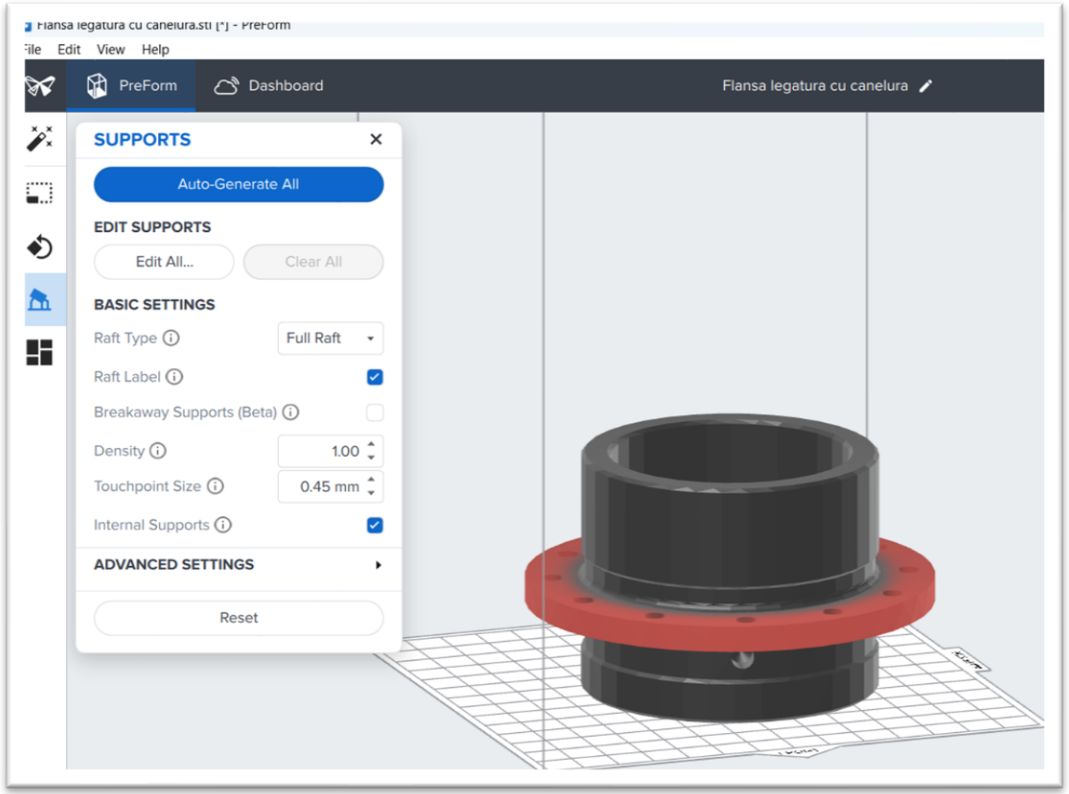
Part 3: Flange.stl file



Orientation X,Y,Z on the worktable of the part



Supports chosen to sustain the part during the 3D Printing process

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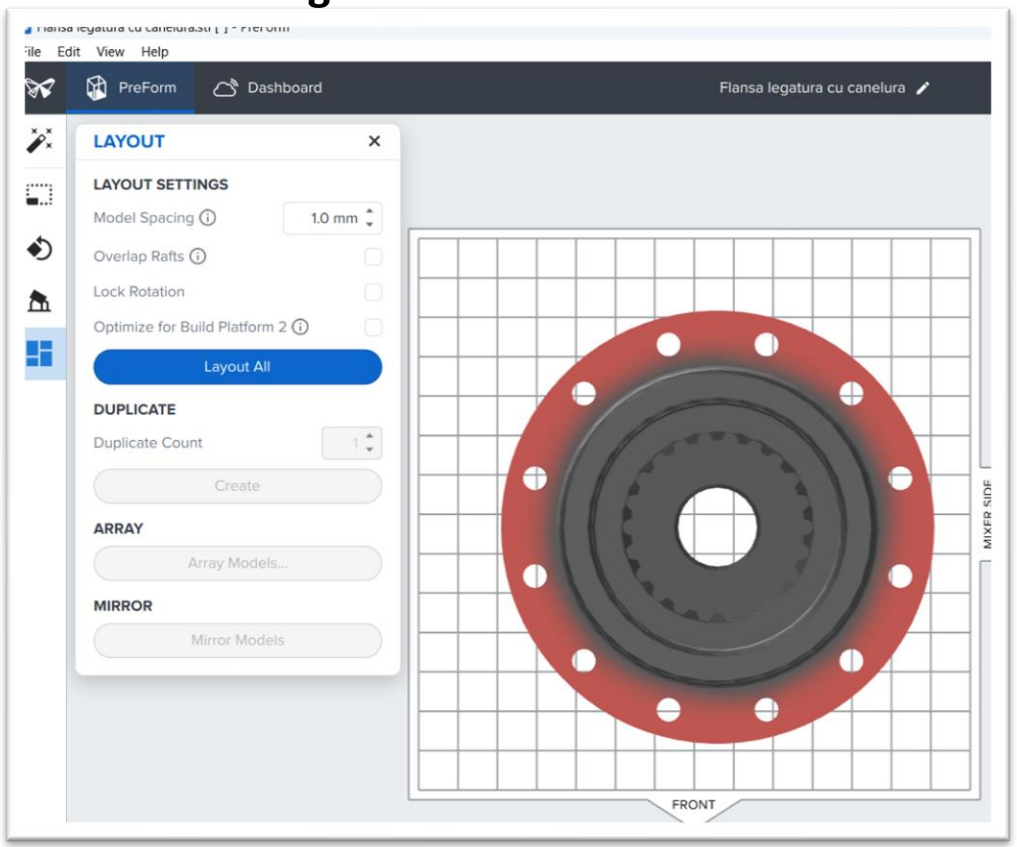
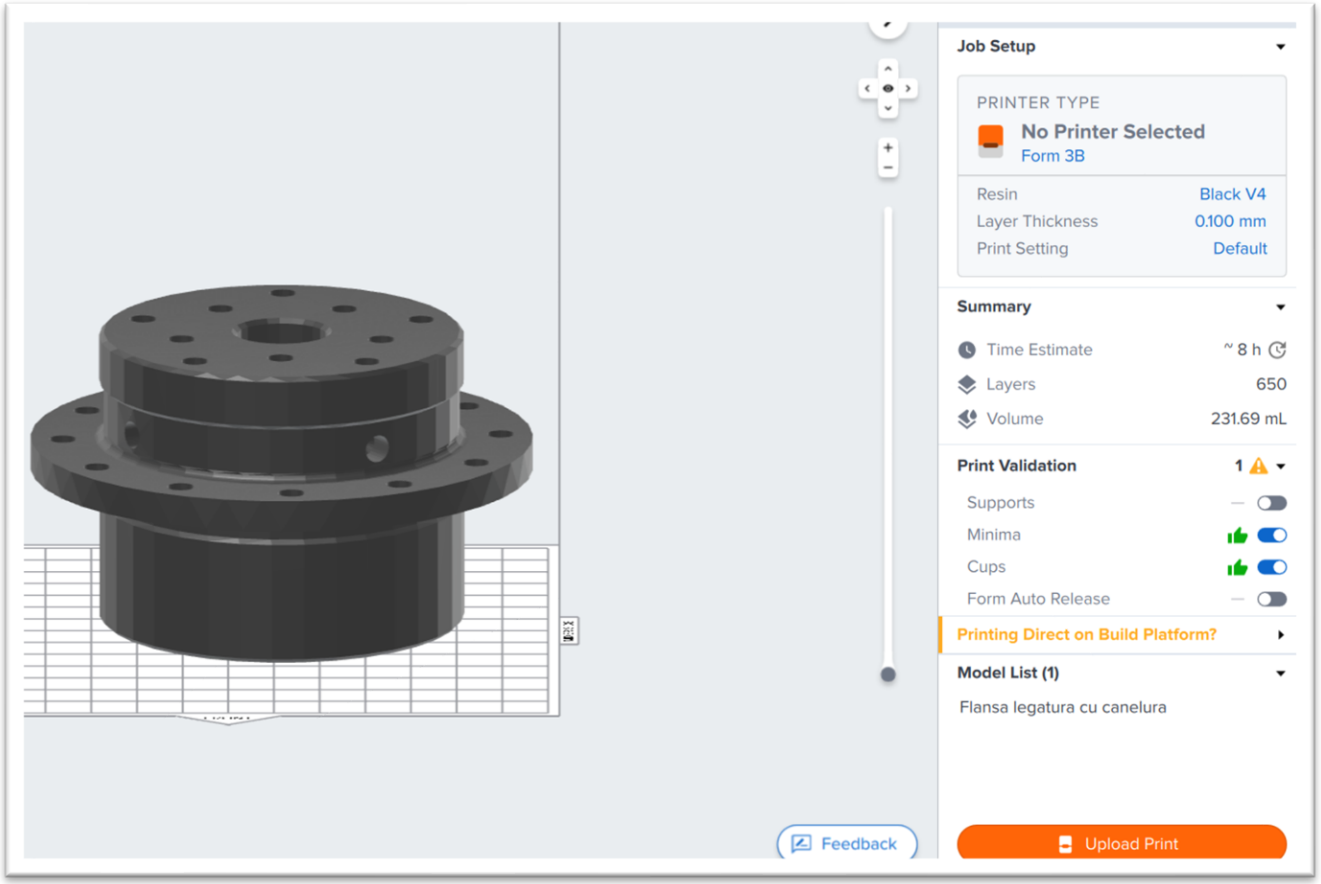
Part 3: Flange.stl file



The layout chosen



The orange button – Start a print

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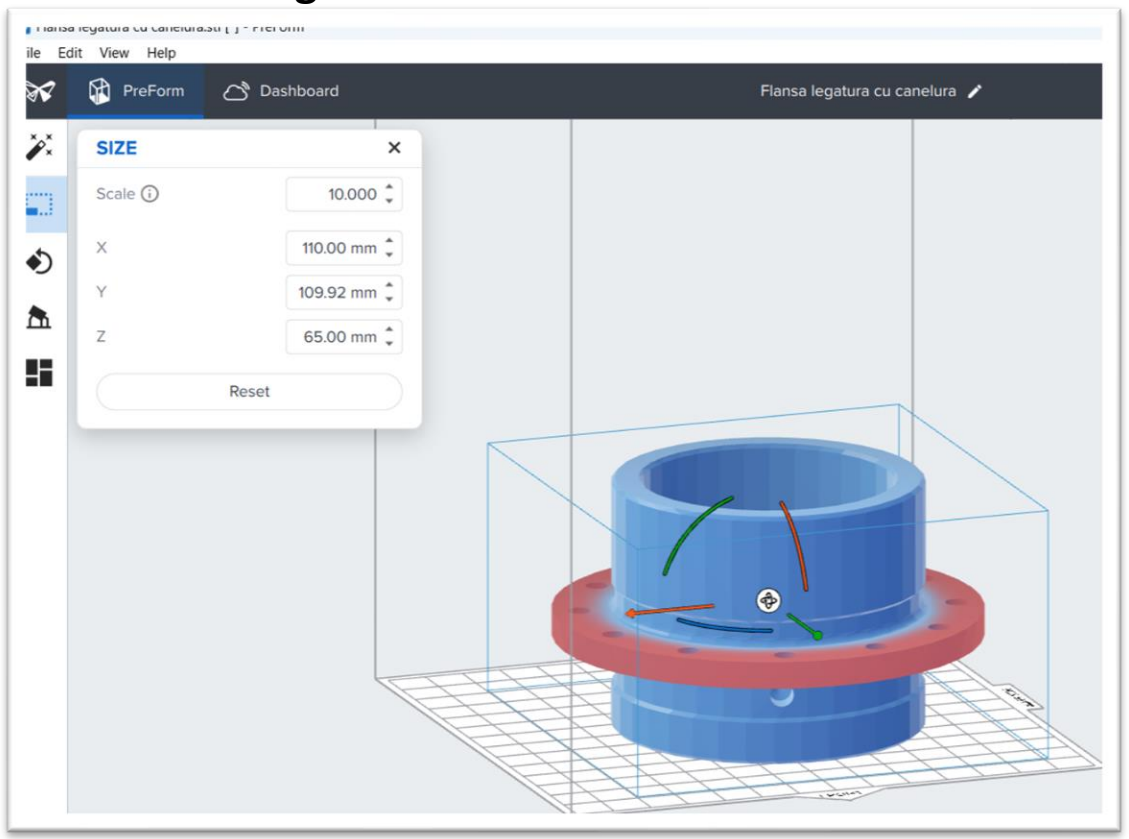
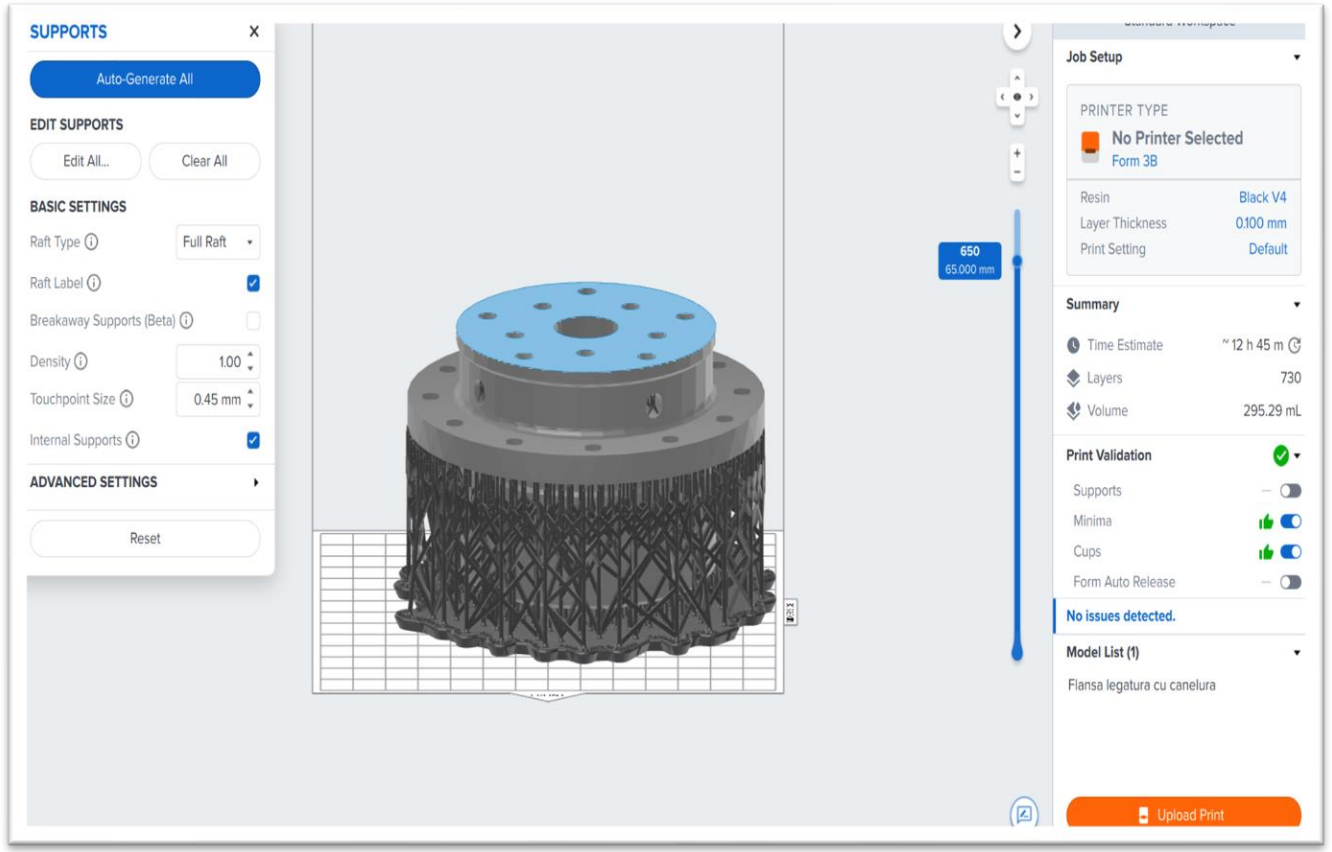
Part 3: Flange.stl file



The scale of flange STL. file on the worktable



Calculating orientation and generating supports

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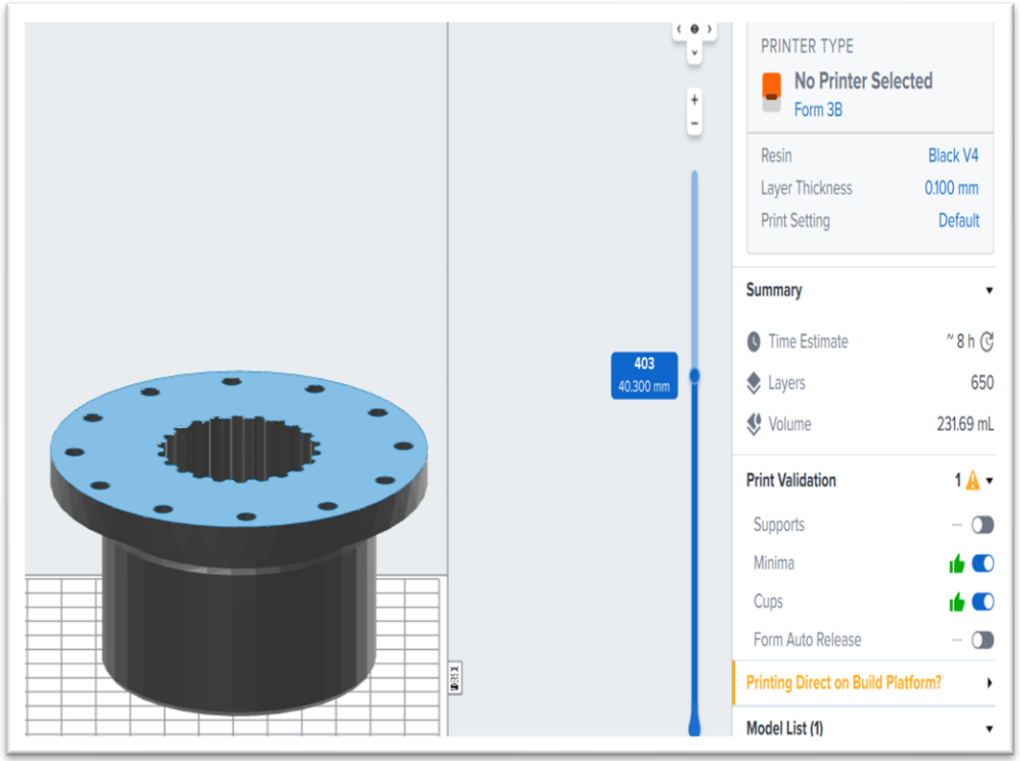
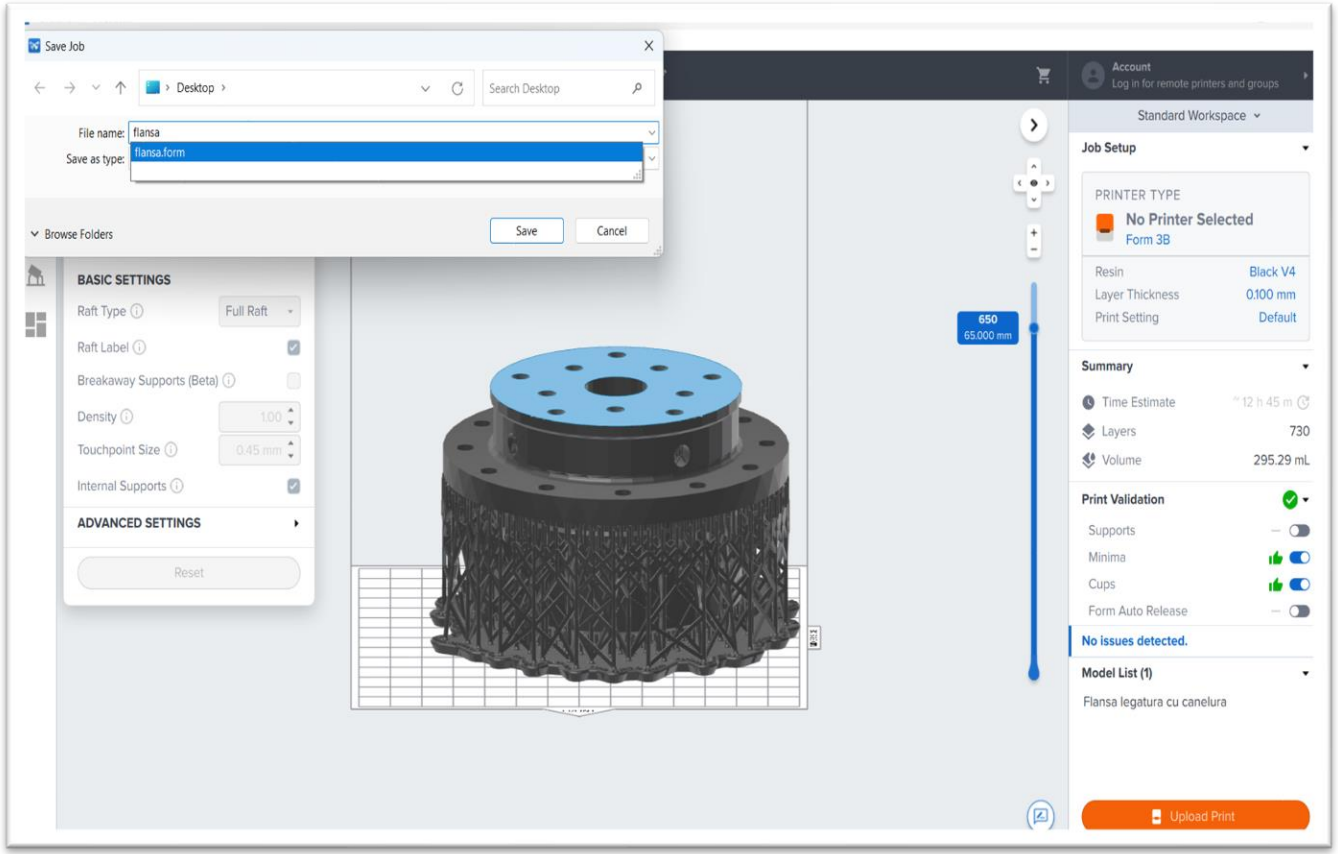
Part 3: Flange.stl file

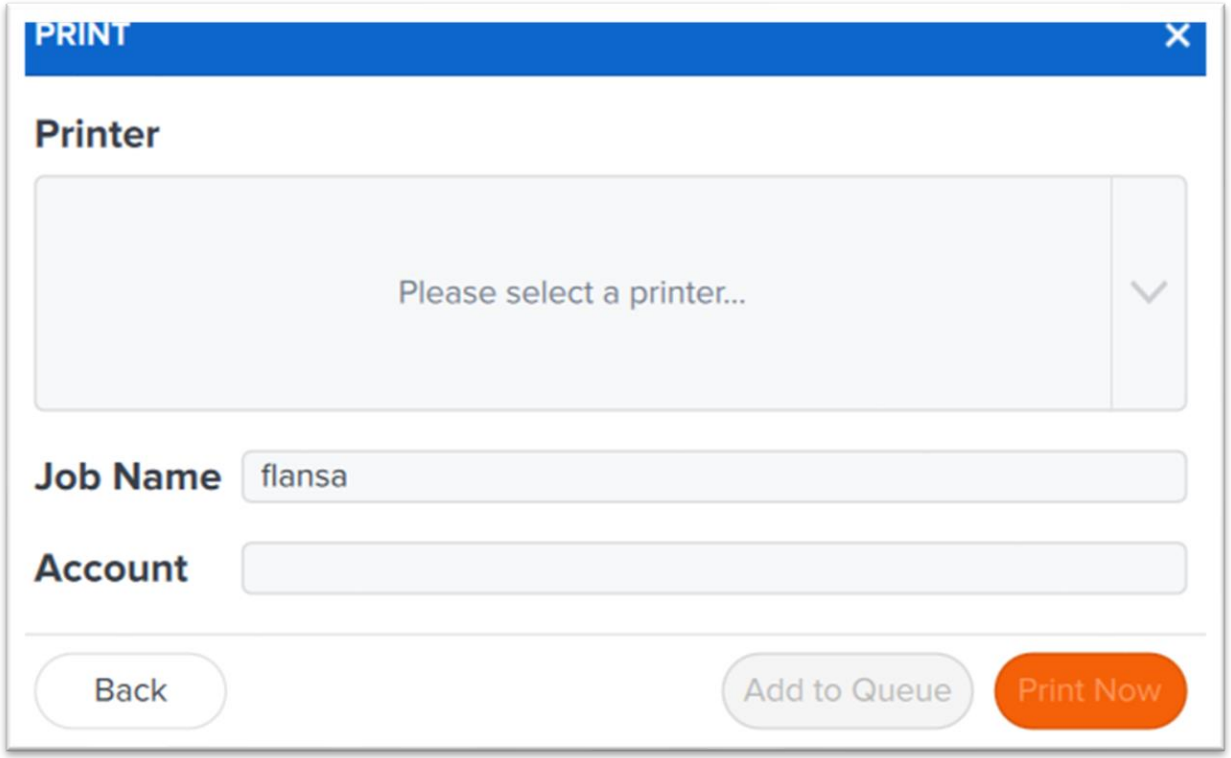


Surface printed at the layer 403

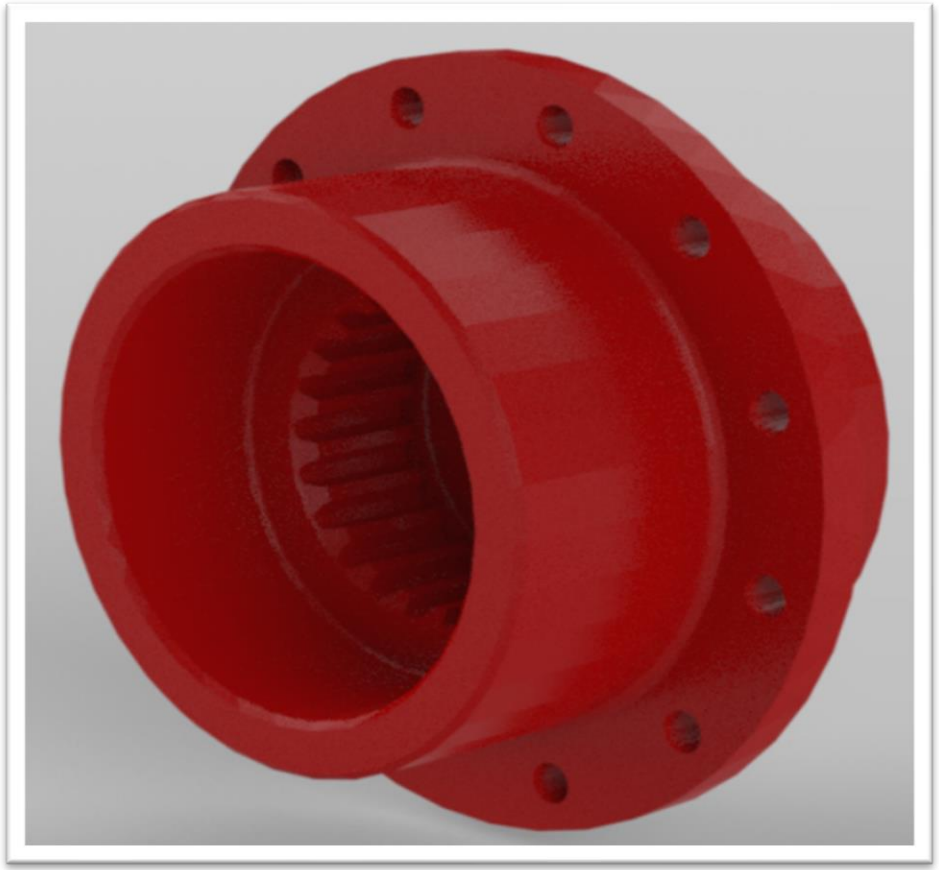


Save the file as Flange with the extension .FORM

Part 3: Flange.stl file



Click on the orange button to print



Flange printed by SLA

Thank you!

Thank you!