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Ultrasint® TPU 01

Rubber like | High shock absorption | Resistance to fatigue

Extended TDS

Complete Technical Documentation and Testing Summary

Version 4.0

Contents

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Technical Data Sheet

Rubber like material, for parts that require shock-absorption, high flexibility and resistance to fatigue.

General Properties	Method	Typical Values
Appearance	-	Natural white powder
Density (printed part)	DIN EN ISO 1183-1	1.1 g/cm³
Density (Bulk Density)	DIN EN ISO 60	0.5 g/cm³
Mean Particle Size d50	ISO 13320	70-90 µm
Glass Transition Temperature (20 K/min)	ISO 11357	-48°C
Melting Temperature (20 K/min)	ISO 11357	120 – 150°C

Tensile Properties	Method	Typical Values	
		X-Direction	Z-Direction
Tensile Modulus[1)]	ISO 527-2, 1A	85 MPa	85 MPa
Ultimate Tensile Strength[2)]	DIN 53504, S2	9 MPa	7 MPa
Elongation at Break[2)]	DIN 53504, S2	280%	150%

Flexural Properties	Method	Typical Values	
		X-Direction	Z-Direction
Flexural Modulus	DIN EN ISO 178	75 MPa	74 MPa
Tear Resistance (propagation, Trouser)	DIN ISO 34-1, A	26 kN/m	26 kN/m
Tear Resistance (initiation, Graves)	DIN ISO 34-1, B	43 kN/m	37 kN/m
Compression Set B (23°C, 72h)	DIN ISO 815-1	24%	24%
Rebound Resilience	DIN 53512	63%	63%

Impact Properties	Method	Typical Values	
		X-Direction	Z-Direction
Charpy Notched, 23°C	DIN EN ISO 179-1	No break	No break
Charpy Notched, -10°C	DIN EN ISO 179-1	46 kJ/m²	44 kJ/m²

Thermal Properties	Method	Typical Values	
		X-Direction	Z-Direction
Vicat/A (10 N)	DIN EN ISO 306	98°C	98°C

Fire, Smoke, Toxicity (FST) properties	Method	Typical Values	
		X-Direction	Z-Direction
Flammability	UL 94	HB (1.6 - 4.2mm)	HB (1.6 - 4.2mm)

Electrical Properties	Method	Typical Values	
		X-Direction	Z-Direction
Dielectric Strength	ASTM D149	4.38 kV/mm	5.81 kV/mm
Volume Resistivity	ASTM D257	$1.45 \cdot 10^{11}$ Ωcm	$6.79 \cdot 10^{10}$ Ωcm
Specific Surface resistivity	IEC 62631-3-2	$5.5 \cdot 10^{11}$ Ω	Not tested

Hardness and Abrasion	Method	Typical Values	
		X-Direction	Z-Direction
Shore Hardness A	DIN ISO 7619-1	88-90	88-90
Abrasion Resistance	DIN ISO 4649	86 mm³	95 mm³

Biocompatibility	Method	Typical Values
Cytotoxicity - Neutral Red	EN ISO 10993-5 (2009)	PASS[3]
In Vivo Sensitization - Local Lymph Node Assay	ISO 10993-10 (2013); OECD Guideline No. 429	PASS[3]
In Vitro Skin Irritation	OECD Guideline No. 439	PASS[3]

Mechanical properties overview

1) Pulling speed 1mm/min
2) Pulling speed 200mm/min
3) For the statement on Biocompatibility data see Chapter: Biocompatibility.
4) If not noted otherwise, all specimens are 3D printed. Samples were tested at room temperature, 23°C.

International Material Data System (IMDS)

This material is listed in the IMDS (International Material Data System), which contains information on materials used in the automotive industry. Access to the database can be granted on request by sharing the IMDS ID with us (sales@forward-am.com).

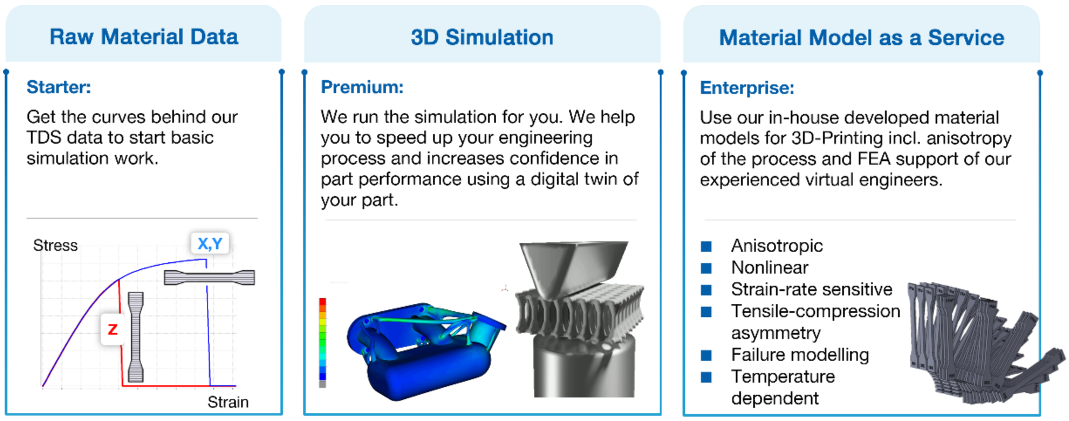
Printing Performance

The combination of 3D printer and material has a huge impact on the quality of the parts produced.

Material Model & FEA Simulation

FEA simulation can be used to predict how different parameters such as temperature and mechanical stress affect the final printed parts. This information can be used to significantly expedite application development, and to optimize the part design to ensure all performance requirements for the application are met. In order to run simulations with a specific material, a material model is required. This model is generated based on a wide range of testing data under different loads and at different temperatures and other relevant conditions.

We can support you with 3D simulation in different ways, ranging from simply supplying you with raw test data, to doing the full simulation for you. These are the 3 options we offer:



Specifically for Ultrasint® TPU 01, below you can find some of the data (at specific temperatures / mechanical loads) we have available in our Ultrasim® Material Model or that we could provide to you for your own simulations. More information is available on request (sales@forward-am.com).

	Available temperatures			Strain rate / loads		Print Orientation / Aniso-tropy
	Low	23°C	High	Quasi static	High speed	
Ultrasint® TPU 01	●	●	●	●	●	●

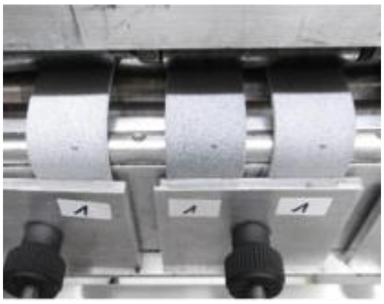
- ● Validated, available as Material Data Set (can be converted into a Ultrasim® Material Model)
- ● Validated, available via Ultrasim® Material Model
- ○ ○ Preliminary

Cycle Mechanical Testing

When a component operates under conditions where it is repeatedly loaded, it can experience cracking or fracturing which can lead to failure. The goal of any fatigue test is to determine how well a product or material can withstand cyclic fatigue loading forces without failure and is a critical measure for many engineering applications such as automotive suspension system parts or industrial machinery parts among others.

Test method and specimens

The tests have been performed according to ASTM Method D1052, also known as ROSS flex test. All samples were printed in XZ direction for this test.



Test set-up of Ross flex measurement of Ultrasint® TPU 01

Results

The result of this test is measured by the possible growth of the incision that was made before the continuous bending was performed. If the cut grows or a beam in the lattice breaks, that could indicate a limitation for certain applications in the market. In some cases, the tests were also performed in post processed parts, both in chemically smoothed samples and coated samples.

ROSS Flex tests	Reference	Etched	Coated (Ultracur3D® Coat F)
	After 100k cycles		
Plate, 23°C, 90°, 2 mm incision	No cut growth	No cut growth	No cut growth
Plate, -10°C, 90°, 2 mm incision	No cut growth	No cut growth	No cut growth
Lattice, 23°C, 90°, no incision	No broken connections	Not tested	Not tested
ROSS Flex tests	**After 1 mio. cycles**		
Plate, 23°C, 60°, 1 mm thickness	No cut growth	Not tested	Not tested
Plate, 23°C, 60°, 2 mm thickness	No cut growth	Not tested	Not tested
Plate, 23°C, 60°, 3 mm thickness	No cut growth	Not tested	Not tested
Plate, 23°C, 60°, 4 mm thickness	Broke after 350k cycles	Not tested	Not tested

Results of fatigue resistance test of Ultrasint® TPU 01

Industrial Chemical Resistance

The resistance of plastic materials against chemicals, solvents and other contact substances is an important criterion of selection for many applications. When contacting such substances, the mechanical properties of plastic materials can be affected. This summary table provides a survey in tabular form of the behavior of Ultrasint® TPU 01 towards common contact substances.

General chemical resistance depends on the period of exposure, the temperature, the quantity, the concentration and the type of the chemical substance. In the case of chemical degradation of polyurethane, the chemical reaction results in cleavage of the molecular chains. This process is generally preceded by swelling. In the course of degradation, polyurethane loses strength, and in extreme cases this can lead to disintegration of the material.

Test method and specimens

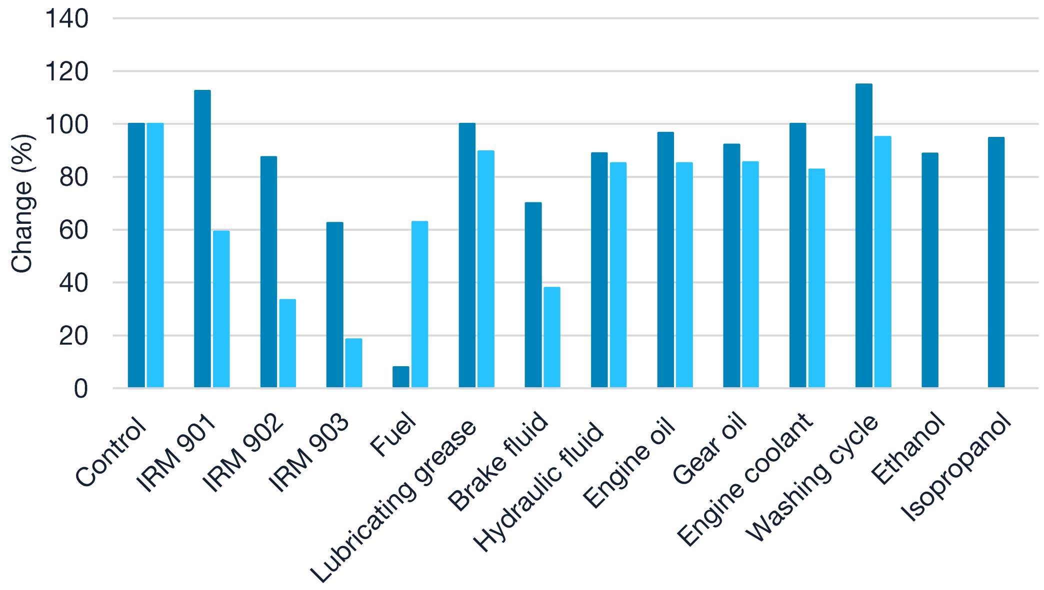
- Test Specimens Standard S2 dumbbells according to DIN 53504

Used hydrocarbons and cleaning chemicals

Fluid	Conditions
IRM 901	100°C for 20 hours
IRM 902	100°C for 20 hours
IRM 903	100°C for 20 hours
Fuel	23°C for 42 days
Lubricating grease Nigrin Mehrzweckfett	23°C for 42 days
Brake fluid Bosch DOT 4	23°C for 42 days
Hydraulic fluid (green) febi 46161	23°C for 42 days
Engine oil - Castrol Edge Professional Long-life III 5W-30	23°C for 42 days
Gear oil - Valvoline Gear oil Valvoline ATF PRO 236.14	23°C for 42 days
Engine coolant - BASF Glysantin G48 ReadyMix/50 blue green	23°C for 42 days
Washing Cycle 10 – With regular soap and softener	1.5h each, 40°C
Ethanol	24h
Isopropanol	24h

Mechanical testing

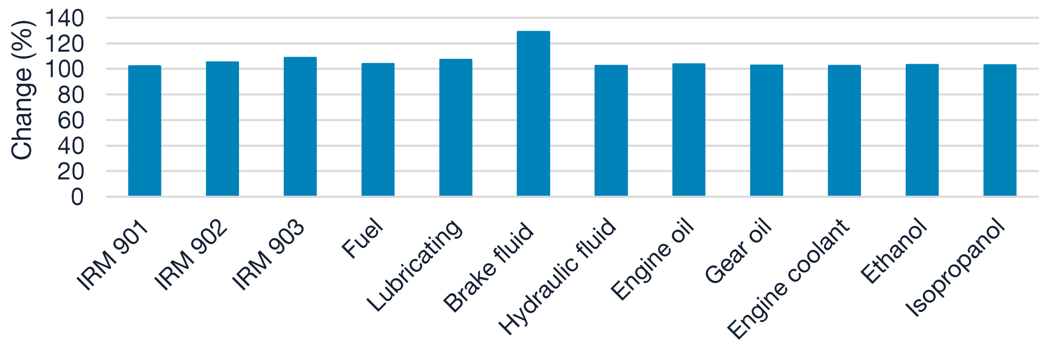
It can be seen from the graphs below that the elongation at break and tensile strength remains stable, for all the specimens after 42 days of exposure. However, Elongation at break changes almost 50% in case of hydraulic oil, engine oil and brake fluid when the material is exposed to these chemicals. Finally, it is important to underline that the shore hardness also stays constant for all specimens.



Change of mechanical performance of Ultrasint® TPU 01 for exposure of chemicals

Volume testing

Slight increase in volume can be seen in some of the chemicals, with the highest change being of almost 30% with Brake fluid.



Change of volume of Ultrasint® TPU 01 for exposure of chemicals

Long-Term UV

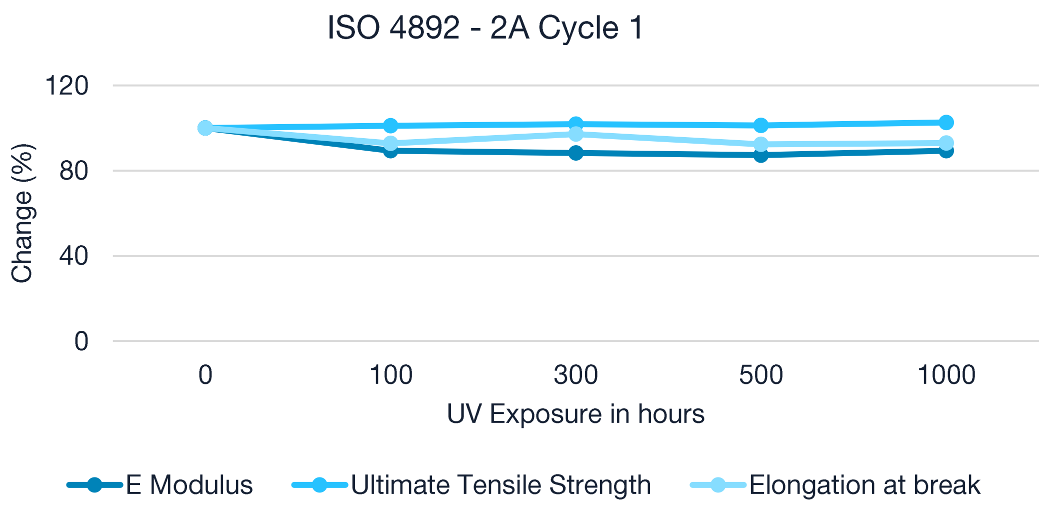
Durability is a key feature for the components in many industries. The materials used in automotive or consumer application for instance, must be put through a variety of severe tests to ensure that they can withstand years of exposure to the elements. Plastics are chemically degraded by the effect of UV radiation. The degree of ageing depends on duration and intensity. In the case of polyurethanes, the effect is seen initially as surface embrittlement. This is accompanied by a yellowing in color and a reduction in mechanical properties. The chemistry behind Ultrasint® TPU 01 (aliphatic) has an intrinsically high UV stability in comparison to aromatic materials where degradation is more prominent.

Test method and specimens

The UV resistance was examined both for outdoor weathering condition use and indoor use using conventional accelerated weathering tests at BASF lab as per the Norm ISO 4892-2:2013 Method A and ISO Norm ISO 4892-2:2013 Method B.

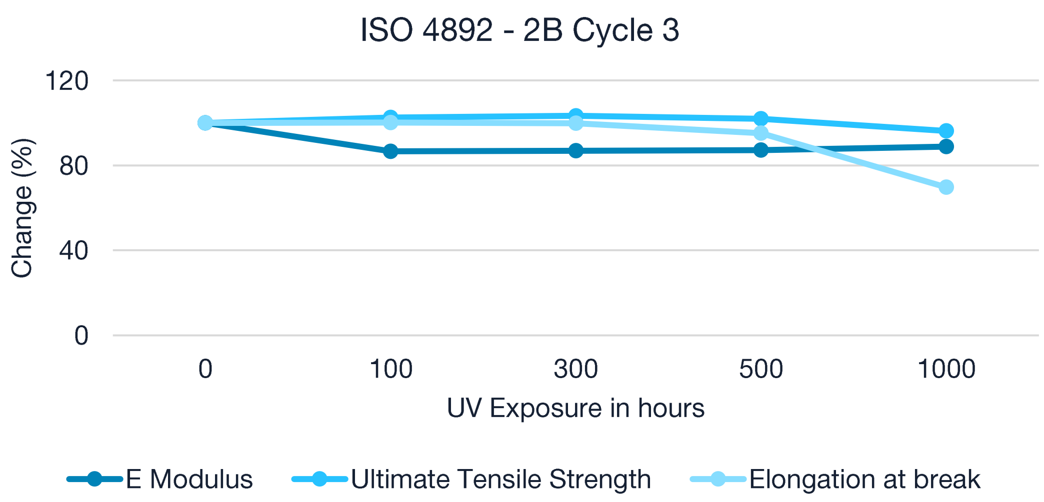
Mechanical Testing

When looking at the mechanical properties of the material after performing the test conditions A, the tensile strength stays constant over time while there is a slight drop in the E modulus and Elongation at break.



ISO 4892 – 2A Cycle 1 Change of mechanical properties over the course of 1000 hours of UV exposure

When looking at the mechanical properties of the material after performing the test conditions B, the E modulus stays constant over time and so does the Elongation at break until exposure time of 500 h. The Tensile strength drops slightly and then stays constant.



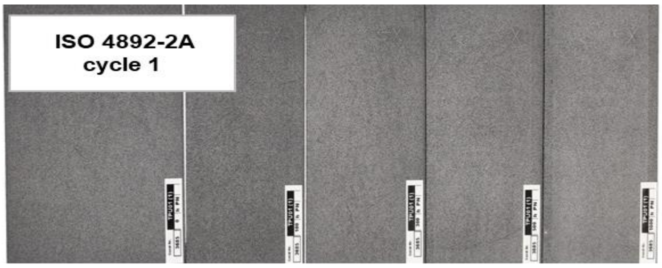
ISO 4892 – 2B Cycle 3 Change of mechanical properties over the course of 1000 hours of UV exposure

Coloration

In order to measure the coloration variations of the different specimens the CIELAB color model was used. Like geographic coordinates – longitude, latitude, and altitude – in the CIELAB color model L*a*b* color values gives one a way to locate and communicate colors.

- L: Lightness
- a: Red/Green Value
- b: Blue/Yellow Value

As appreciated below, for both test conditions mentioned above, after 1000 h, besides some slight staining for the water in method A or some slight darkness in method B, one can confirm that the material plates have good resistance to change its color characteristics, has a good color fastness, since the model L*a*b* color values stay constant. The test results below reflect the durability of Ultrasint® TPU 01.



0h	100h	300h	500h	1000h
L-Value: 47,6	L-Value: 43,8	L-Value: 45,5	L-Value: 45,2	L-Value: 46,1
a: -0,1	a: -0,2	a: -0,2	a: -0,1	a: -0,2
b: -1,0	b: -0,8	b: -0,8	b: -0,8	b: -0,9

Effect of UV exposure on color of the specimens

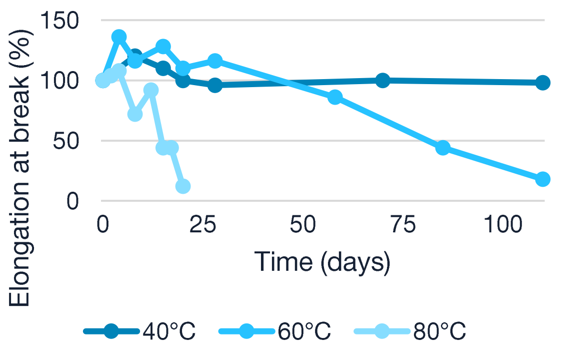
Hydrolysis Resistance

Overall, hydrolysis resistance is important because it helps to ensure the stability, safety, and effectiveness of many different products and materials that are exposed to water. If polyester based polyurethanes are exposed for lengthy periods to hot water, moisture vapor or tropical climates, an irreversible break-down of the polyester chains occurs through hydrolysis. This results in a reduction in mechanical properties. This effect is more marked in flexible grades, where the polyester content is correspondingly higher than in the harder formulations.

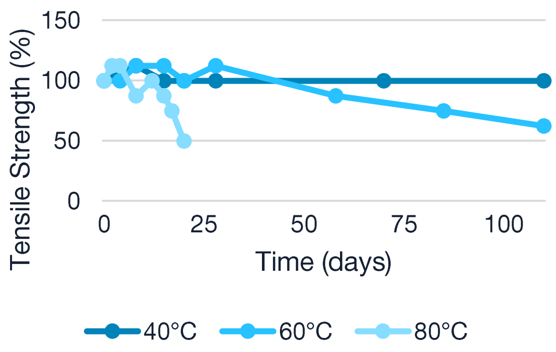
Test method and specimens

Storage of S2 tensile bars (X-direction), immersed in water, at various temperatures (40°C, 60°C, 80°C).
Storage of S2 tensile bars (X-direction), immersed in sea water at room temperature.

Results



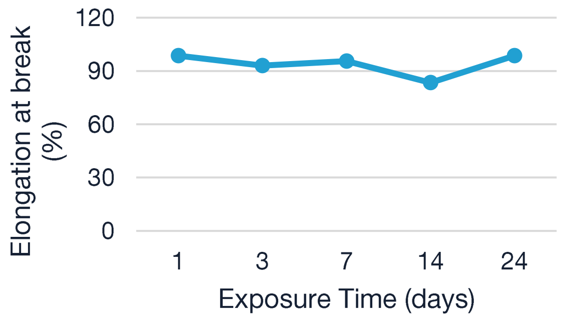
Change of elongation of break of Ultrasint® TPU 01 over time of water exposure



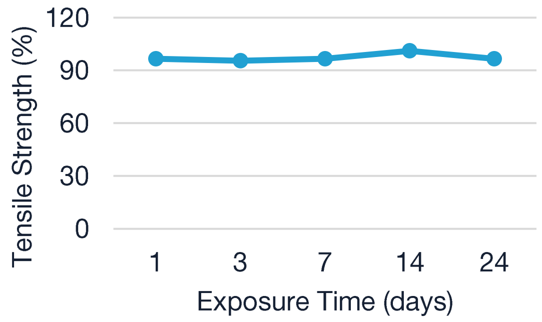
Change of tensile strength of Ultrasint® TPU 01 over time of water exposure

Due to a good stabilization, a degradation of polyester-based Ultrasint® TPU 01 is rarely experienced at room temperature, at 40°C the printed parts properties stay constant for over >100 days.

Like for all polyester-based TPUs, water at high temperature can be a problem, therefore with Ultrasint® TPU 01 parts in contact with water at high temperature (>60°C) should be avoided to avoid a decrease in mechanical performance.



Change of Elongation of break of Ultrasint® TPU 01 over time of sea water exposure



Change of Tensile Strength of Ultrasint® TPU 01 over time of sea water exposure

Like the exposure of Ultrasint® TPU 01 to water below 40°C, the mechanics keep being stable when being in contact with sea water up to 24 days.

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Air and Fluid Tightness

Air and fluid tightness are important for many industries and applications because they help to prevent leaks, contamination and loss of efficiency. The goal of this test is to determine how well can Ultrasint® TPU 01 parts achieve watertight properties without any additional post processing.

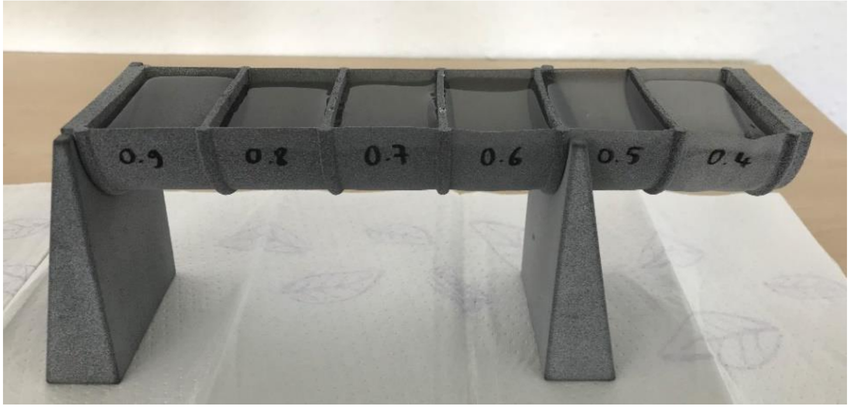
Fluid tightness is key for applications such as ducts, deposits, waterproof covers or hydraulic/ pneumatic systems that work with water, oil, air or other substances, even under pressure. These are the main variables of design, which define the maximum pressure any given part can withstand:

- Wall thickness
- Shape
- Temperature
- Pressure
- Type of fluid

Water Tightness

Certain applications, such as fluid reservoirs or deposits, require a leakage test. The watertightness characterization test has been performed using two different shapes, hollow spheres and vertical cylinders, and seven different wall thicknesses and with water fluid to room temperature.

Testing conditions for water tightness with hollow spheres



Testing conditions for water tightness with vertical cylinder

The results after 1 week were the following:

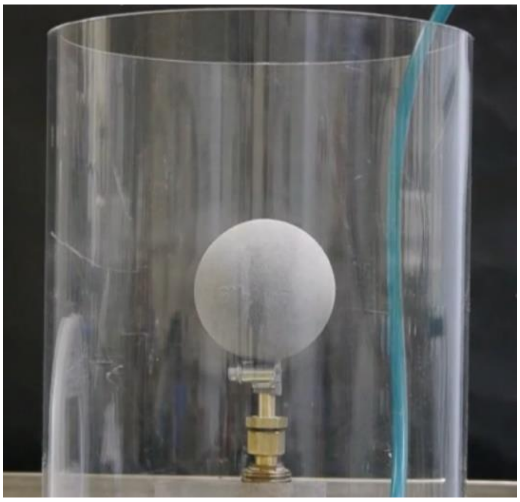
Wall thickness	Hollow spheres	Vertical cylinder
0.4 mm	not watertight	watertight
0.5 mm	not watertight	watertight
0.6 mm	watertight	watertight
0.7 mm	watertight	watertight
0.8 mm	watertight	watertight
0.9 mm	watertight	watertight
1.0 mm	watertight	

Testing results after 1 week

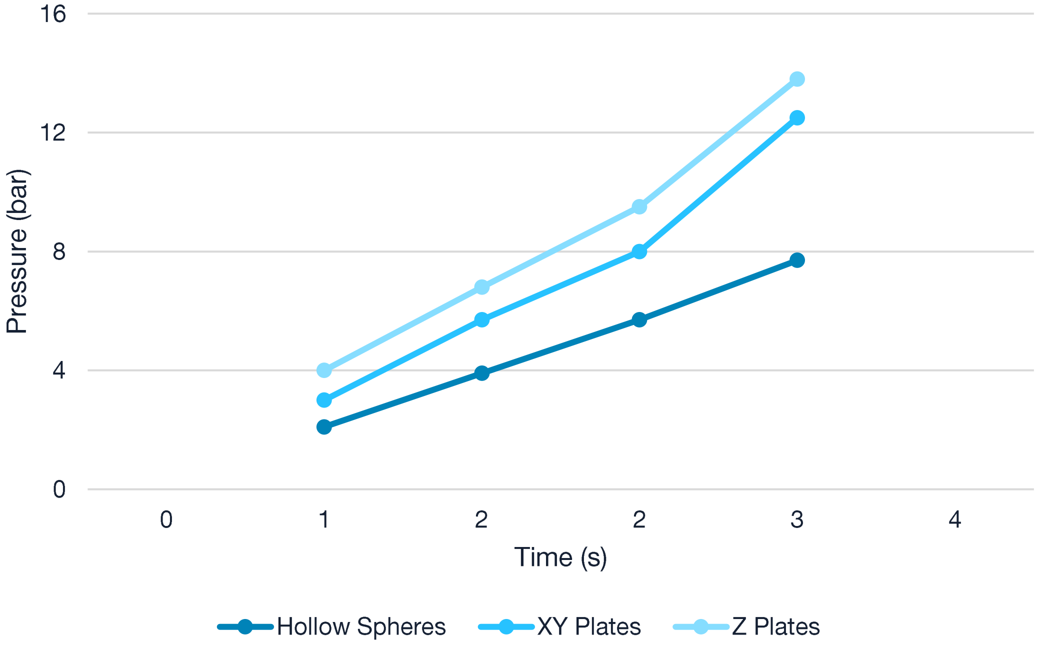
Burst Pressure

The pressure resistance of components is important in many areas such as security, cost or overall part performance. The results on such test are key to meet the requirements of hydraulic components, automotive components or hoses, pipes and pipe connections for example.

After choosing different geometries to be tested, the pressure is incremented from 25mbar/s = 1.5 bar/min until part breaks. The tested geometries wee hollow spheres, plates printed horizontally in XY and vertically in Z, each in two wall thicknesses to obtain good reproducibility.



Test set-up for measuring burst pressure

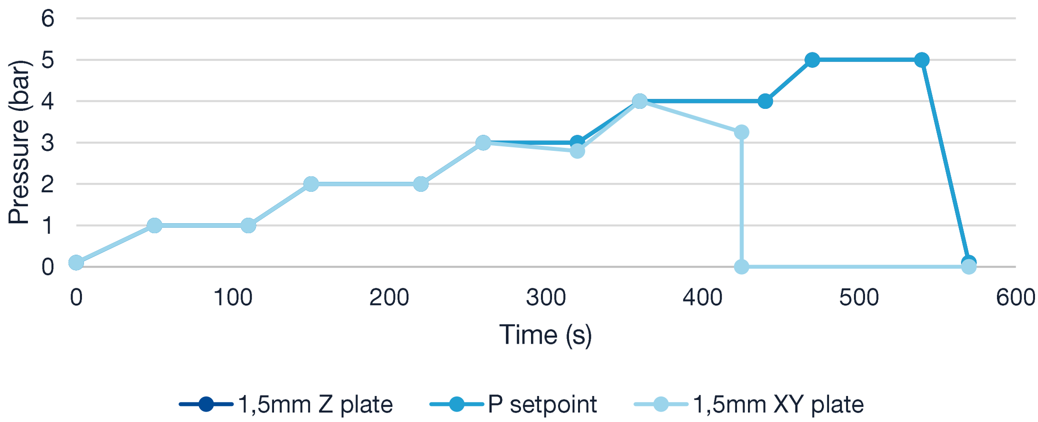


Burst pressure of various geometries in Ultrasint® TPU 01

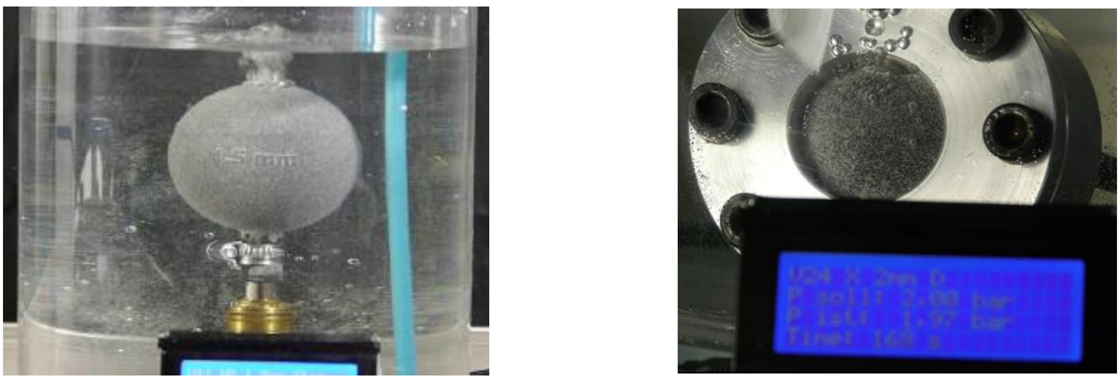
As can be seen in the graph, good homogeneity between XY and Z directions is accomplished in the plates which can withstand higher burst pressures than plates. This could be due to small inhomogeneities in wall thicknesses and varying overlap of printed layers in the sphere, which leads more easily to weak spots.

Air Tightness

After choosing different geometries to be tested, the pressure is incremented in steps from 25mbar/s = 1.5bar/min until part breaks or up to a maximum of 5 bar. The tested geometries were hollow spheres, plates printed horizontally in XY and vertically in Z in different thicknesses. The main difference between the air tightness test and the burst pressure test is that the first is performed under water and leakage is detected through bubble formation and recorded pressure drop.



Air tightness of various geometries in Ultrasint® TPU 01



Test set-up for measuring air tightness

Wall thickness	Hollow spheres	XY plates	Z plates
1 mm	not airtight	not airtight	airtight up to 2 bar
1.5 mm	not airtight	airtight up to 2 bar	airtight up to 5 bar
2 mm	not airtight	airtight up to 2 bar	airtight up to 5 bar
3 mm	not airtight	airtight up to 4 bar	airtight up to 5 bar

Results of air tightness measurement

Flame and Temperature Resistance

Flame Resistance Properties

Ultrasint® TPU 01 does not contain any flame retardants, therefore the flammability behavior is in principle comparable to regular plastics.

Two measurements were done for flame resistance, UL 94 and FMVSS 302 specially for car interior applications.

UL 94 --> HB rating for t ≥ 1.0mm

Plastics for Additive Manufacturing E506048
Guide Information
Process Category: Powder Bed Fusion
☑ View Blue Card Format

BASF 3D Printing Solutions GmbH
Speyerer Str. 4, Heidelberg 69115 DE

Ultrasint TPU01(#)(R80)
Thermoplastic Polyurethane (TPU), furnished as powder

Color	Min. Thk (mm)	Flame Class	HWI	HAI	GWIT	GWFI	RTI Elec	RTI Imp	RTI Str
GY	0.75	-	-	-	700	675	50	50	50
	1.0	HB	-	-	675	650	50	50	50
	1.5	HB	-	-	675	650	50	50	50
	3.0	HB	-	-	675	650	50	50	50

Comparative Tracking Index (CTI): 0
Dielectric Strength (kV/mm): 4.38
High-Voltage Arc Tracking Rate (HVTR): -
IEC Comparative Tracking Index (Volts Max): -
IEC Ball Pressure (°C): -
ISO Tensile Strength (MPa): -
ISO Tensile Impact (kJ/m^2): -

Inclined Plane Tracking (IPT) kV: -
Volume Resistivity (10^x ohm-cm): 10
High Volt, Low Current Arc Resis (D495): -
ISO Charpy Impact (kJ/m^2): -
ISO Heat Deflection @1.80 MPa (°C): -
ISO Flexural Strength (MPa): -
ISO Izod Impact (kJ/m^2): -

Process Category: Powder Bed Fusion
Printing Process Designation Number: 1

Build Plane: Horizontal & Vertical
Laser Power (Watts): -
Layer Thickness (μm): 100
Scan Speed (m/s): -
Hatch Spacing (mm): -
Scan Strategy: -
Post Processing Method: Bead blasting: Glass beads, 300-400μm, with 4-6 bars Air Pressure.
For use with UL Listed printer: HP Jet Fusion 5200 3D Printer, HP Jet Fusion 5210 3D Printer, HP Jet Fusion 5210 pro 3D Printer
Printer Preset: balanced

Limited properties and ratings assigned to samples produced by the Additive Manufacturing technique representing a specific set of printing parameters and build strategy. Other print parameters and build strategies may result in significantly different results.

(#) - For use with Fusing and detailing agents HP 3D600, HP 3D700 or HP 3D710.
(R80) - Material is approved for use with Reclaimed powder of 80%

IEC/ISO small-scale test data does not pertain to building materials, furnishings and related contents. IEC/ISO small-scale test data is intended solely for determining the flammability of plastic materials used in the components and parts of end-product devices and appliances, where the acceptability of the combination is determined by UL.

Report Date: 2020-03-13
Last Revised: 2020-03-17
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UL94 Blue Card

FMVSS 302 (car interior applications)

Heat stability tests are of central importance for materials in car interiors and aim to determine the burn resistance capabilities of materials under standardized conditions.

- Tests are subject to geometry
- Thin plates or thin/fine lattices are to have the worst results
- Test plates 356x102 mm:

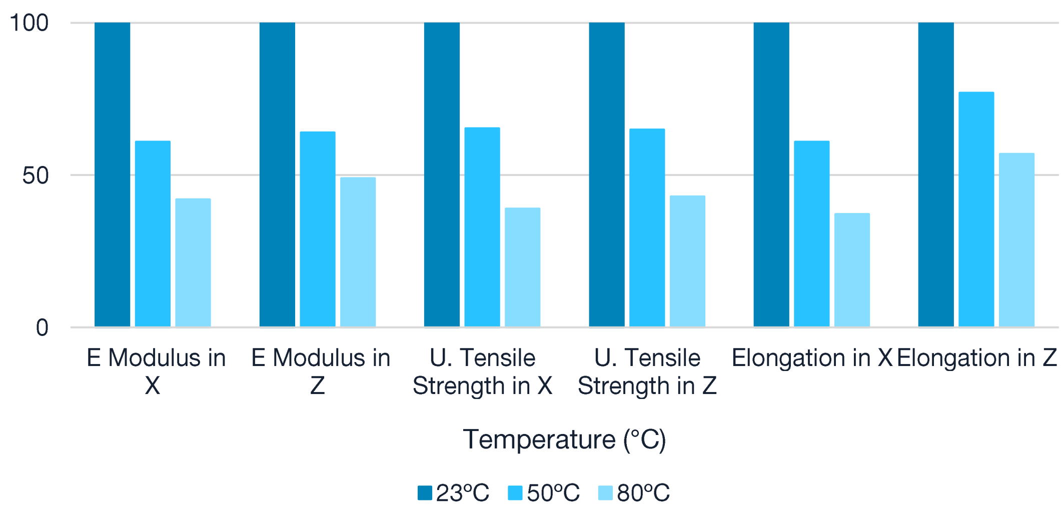
Result of 5 samples:

Orientation	Thickness	Max. burning rate (limit ≤ 102mm/min)
XY	1.16 mm	97 mm/min
Z	1.32 mm	63 mm/min

Results of flammability resistance test of Ulrasint® TPU 01

Temperature Resistance

The temperature performance of a material is key to enable a broad range of applications and industries. To validate the temperature performance of Ultrasint® TPU 01, different temperature exposure tests were performed and mechanical tests analyzed. Even though the shape and integrity of the 3D printed parts were not compromised, there is a loss in mechanical properties with the increase of temperature. Results of the testing can be seen below:



Change of mechanical properties in high temperature exposure in X and Z direction

Vehicle Interior Air Quality

When a component needs to go inside a vehicle interior it is a must that it is important that it passes stringent odor, fogging, and emissions standards required for interior automotive applications. Automotive requirements might differ from company to company.

Standards and General Targets

	Test Method	Description	General Target[5)]
Odor	VDA 270	Determination of the olfactory characteristics of car materials	< 3
Formaldehyde	VDA 275	Control of formaldehyde emissions	< 5 mg/kg
Volatile Organics (VOC)	VDA 276	Determination of organic substances as emitted from automotive interior products using a 1 m^3 test cabinet	
Volatile Organics (VOC)	VDA 278	Thermal desorption. Emissions of volatile compounds from materials	< 220 ppm
Fogging	DIN 75201 Method B	Fogging behavior. Condensation of semi-volatile compounds that generate lack of visibility	< 1 mg
Semi-Volatile Organics (FOG)	VDA 278	Emissions of semi-volatile compounds from materials	< 220 ppm

Testing standards and general targets for vehicle interior air quality

5) Limits are manufacturer dependent, given are just typical limit values as an indication.

Results

The table below displays the results of analysis conducted on interior parts produced from Ultrasint® TPU 01. The test specimens have been sandblasted and further processed after printing. Details and further data are available upon request.

SB = Sandblasted
PR = Processing
CS = Chemically Smoothed
CL = Colored with Colored Ultracur3D® Coating

Name	Odor	Formaldehyde	Volatile Organics (VOC)	Volatile Organics (VOC)	Fogging	Semi-Volatile Organics (FOG)
Method	**VDA 270**	**VDA 275**	**VDA 276**	**VDA 278**	**DIN 75201 Method B**	**VDA 278**
SB	< 3	< 0.3 mg/kg	Available on request	690–1032 ppm	5.9 mg	461–532 ppm
SB + PR				< 100 ppm	0.1 mg	< 200 ppm
SB + CS + CL + PR	2.7			< 100 ppm	0.8 mg	< 200 ppm
General Target	**< 3**	**< 5 mg/kg**		**< 220 ppm**	**< 1mg**	**< 220 ppm**

Results of VDA tests

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Biocompatibility

Product: Ultrasint® TPU 01 for HP Jet Fusion

Revision: 09th of February 2022

3D printed test items of the above stated product have fulfilled the requirements of tests as stated below:

Cytotoxicity Testing- Neutral Red:
(EN ISO 10993-5 (2009))
In vitro Skin Irritation Testing- Human Skin Model:
(OECD Guideline No.439)
In vivo Sensitization Testing- Local Lymph Node Assay:
(ISO 10993-10 (2013) OECD Guideline No.429)

Sampling preparation: The test specimens were dry ice blasted and handled only with disposable medical gloves. The test specimens were wrapped in aluminum foil for shipment to the testing laboratory.

The biocompatibility tests were recorded on test specimen of the referenced product to show compatibility of the material in general. The biocompatibility tests listed are not part of any continuous production protocol. The test assessments reflect only the test specimen and have to be retested on the final product. It remains the responsibility of the de-vice manufacturers and /or end-users to deter-mine the suitability of all printed parts for their respective application.

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forward-am.com +49 6221 67417 900 sales@forward-am.com

Biocompatibility & vapour smoothing

Product: Ultrasint® TPU 01 for HP Jet Fusion & vapour smoothing

Revision: 13th of February 2022

3D printed test items of the above stated product have fulfilled the requirements of tests as stated below:

Cytotoxicity Testing- Neutral Red:
(EN ISO 10993-5 (2009))
Human Skin Irritation Test:
(EN ISO 10993-10 (2013))[6)]
In vitro Sensitization Testing- KeratinoSens™
(prEN ISO 10993-10 (2020))

6) Patch test on 10 volunteers

Sampling preparation: The test specimens were dry ice blasted and handled only with disposable medical gloves. The test specimens were wrapped in aluminum foil for shipment for vapour smoothing externally with an AMT Post Pro 3D.

According to our testing institutes the test result show no indication against the use of the test specimen in skin contact application.

The biocompatibility tests were recorded on test specimen of the referenced product to show compatibility of the material in general. The biocompatibility tests listed are not part of any continuous production protocol. The test assessments reflect only the test specimen and have to be retested on the final product. It remains the responsibility of the de-vice manufacturers and /or end-users to deter-mine the suitability of all printed parts for their respective application.

Food Contact

Ultrasint® TPU 01 is not produced according to any food contact guidelines and **does not have food contact approval**. The HP fusing agent does not have food contact approval. Applications close to food, but with no direct contact, e.g. robotic grippers: have to be investigated case-by-case, with a risk analysis.
Alternatively, there would be the possibility to use a functional barrier, e.g. FDA accepted functional barriers are aluminum foil, and polyethylene terephthalate film (at least 25 μm thick for room-temperature applications).

Regulatory documents

In terms of certification, Ultrasint® TPU powders contain regulatory documents for:

- Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)
- Restriction of Hazardous Substances (RoHS)
- Substance of Very High Concern (SVHC)
- End-of-Life Vehicle (ELV)
- Global Automotive Declarable Substance List (GADSL)

Ultrasint® TPU powders are listed in the International Material Data System (IMDS) for automotive industry. These and further certifications are available upon request.

Sustainability (LCA & Recycling)

The sustainability concept of Ultrasint® TPU 01 is set up on three main approaches.

1. A **life-cycle assessment (LCA)** of the material production from granulate to powder according to ISO 14040:2006 and ISO 14044:2006 has been executed and reviewed by external third party to analyze the emission of carbon per kg of TPU. The study serves as a baseline for better understanding the main contributor to the carbon footprint and how to reduce the emission. The analysis is available on request for free.

Confidential

Version: 1.1

forward am

Date

Name of Requestor

Company Name

Company Address

Forward AM Technologies GmbH
Speyerer Strasse 4, 69115 Heidelberg, Germany

Dear Customer,

Please find the *Material LCA* report of the requested Forward AM product. Please note that communication, sharing, disclosing or disseminating of this document in whole or in part to any third parties or entities without prior written consent from Forward AM Technologies is prohibited.

Ultrasint® TPU01

Life Cycle Assessment
ACCORDING TO ISO 14040 : 2006
AND ISO 14044 : 2006

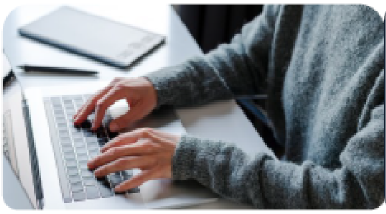
System boundaries: Cradle to gate. (excluding packaging)
Functional unit: 1kg of powder
Data sources: Primary data from Forward AM, background data from reference Databases: Gabi and Plastics Europe.
Cut-off rules: No significant cut-off (<5% of total mass and energy inputs)
LCA practitioner: Forward AM sustainability department
LCA reviewer: Gingko 21 - 8 Rue du Conseil de l'Europe, 91300 Massy – France
Methods used: EF 3.0 Method
Printed part LCA: In order to understand the environmental impact of printed parts made from this material please reach out to sales@forward-am.com and visit our webpage Ultrasim®3D Sustainability Analysis

Impact category	Value
EF 3.0 Acidification [Mole of H+ eq.]	1.30E-02
EF 3.0 Climate Change - total [kg CO2 eq.]	7.99
EF 3.0 Ecotoxicity, freshwater - total [CTUe]	68.21
EF 3.0 Eutrophication, freshwater [kg P eq.]	1.54E-05
EF 3.0 Eutrophication, marine [kg N eq.]	4.10E-03
EF 3.0 Eutrophication, terrestrial [Mole of N eq.]	4.31E-02
EF 3.0 Human toxicity, cancer - total [CTUh]	1.92E-09
EF 3.0 Human toxicity, non-cancer - total [CTUh]	7.09E-08
EF 3.0 Ionising radiation, human health [kBq U235 eq.]	1.05
EF 3.0 Land Use [Pt]	21.18
EF 3.0 Ozone depletion [kg CFC-11 eq.]	5.06E-11
EF 3.0 Particulate matter [Disease incidences]	9.39E-08
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	1.42E-02
EF 3.0 Resource use, fossils [MJ]	153.05
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	8.90E-07
EF 3.0 Water use [m³ world equiv.]	1.15

The present study and its conclusions are based on the analysis of the life cycle steps of product systems and system boundaries for the described function unit. Transfer of these results and conclusions to other production methods or products is expressly prohibited. Partial results may not be communicated to alter the meaning, nor may arbitrary generalization be made regarding the results and conclusions. Forward AM data reflect the situation at the time such data have been collected and Forward AM shall be under no obligation to update the Forward AM evaluation data. Any Forward AM environmental evaluation Data are provided to you to the best of Forward AM's knowledge. However, Forward AM Data are based on certain presumptions and approximations, further explained in this report that consequently may impact the accuracy of the Forward AM Data. Forward AM Data shall not, to the extent permitted by applicable law constitute any representation or warranty of any kind, whether expressed or implied, and shall not relieve you from undertaking your own investigations and tests. Accordingly, any liability of Forward AM about the data, including, but not limited to its accuracy, quality, completeness, or fitness for particular purpose shall be excluded to the fullest extent permitted by applicable law. You explicitly accept this exclusion / limitation of liability.

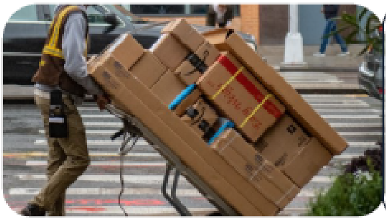
Example of Life-Cycle Assessment Document for Ultrasint® TPU

2. Even though Ultrasint® TPU 01 has already a high printing refresh rate of 80/20, there might be some cake powder or agglomerates which won't be used any further. Forward AM offers to take back these leftovers as well as printed parts from worn out application to give them a second life after **recycling into granulate**.

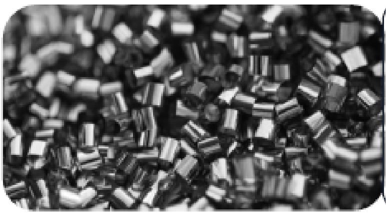


1. CONTACT US
Email us at sustainability@forward-am.com with your company name, contact person, interest in recycling TPU powder and/or parts, and the quantity available.

2. PREPARE THE PACKAGE
Ensure to pack TPU powder and TPU parts. **Label each package using the labels we provided via email**. These labels are essential for handling during shipment.



3. SHIP IT
Plan to send your recyclable material back to us coinciding with your next material delivery. This process ensures efficient restocking of materials and maintaining a sustainable cycle.



4. RECYCLE
Forward AM recycles TPU by-products and waste, effectively converting them back into usable pellets. This sustainable approach ensures the efficient reuse of materials.

REQUIREMENTS FOR RECYCLING:
- All powder and parts must be clean and dry.
- Avoid cross-contamination with other materials (e.g., blast media from depowdering or assembled parts).
- Minimum quantity: 200kg for powder and 50kg for parts.

✅ RECYCLABLE:
- TPU Powder: Includes cake powder and agglomerates
- TPU Printed Parts

❌ NOT RECYCLABLE PARTS:
- Dyed, coated, or vapor smoothed
- Assembled or glued to different materials

QUALITY ASSURANCE: BASF Forward AM can conduct incoming goods inspection. In case of non-conformity, we will dispose of the material, with the cost borne by the supplier.

Recycling Take-Back Program of Ultrasint® TPU