White paper

Fluid tightness characterization I

This document includes the first rounds of results of tests done to characterize the fluid tightness of printed parts using HP Multi Jet Fusion (MJF) technology. Additional results will come in the following technical papers published.

Executive summary

HP MJF-printed parts using HP 3D High Reusability PA 12 achieve watertight properties without any additional post processing. Therefore, HP MJF printed parts could be used as deposits or pipelines that work with water, even under pressure.

These are the main variables of design, which define the maximum pressure any given part can withstand:

- Wall thickness
- Shape
- Temperature
- Type of fluid

These are the **recommended values** to have fluid vessels (deposits or pipelines) working with water under pressure at 25°C, over a temporary period of time:

Wall thickness	3 bar	10 bar	20 bar
1.25 mm	Recommended	Not recommended	Not recommended
2.5 mm	Recommended	Recommended	Not recommended
4 mm	Recommended	Recommended	Recommended

Vessel shape	3 bar	10 bar	20 bar
Spherical	Recommended	Recommended	Recommended
Cylindrical	Recommended	Recommended	Recommended
Cubic	Recommended	Break	Break

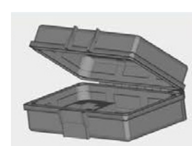
The best shape to work with fluids under pressure is a sphere, because the pressure is better distributed and there are no flat surfaces, which will deform and break easier. Therefore, it is recommended to design fluid vessels as close to a spherical shape as possible, because this will help to withstand higher pressures.

HP 3D High Reusability PA 12 has high chemical resistance to a wide variety of commonly used fluids in the industry. In the following table, the main groups of fluids that could be used with HP 3D High Reusability PA 12 fluid vessels are listed.

Fluid	Chemical behavior
Diluted alkalis	No effect
Concentrated alkalis	No effect
Hot water	Moderate effect
Chlorine salts	No effect
Alcohol	No effect
Esters	No effect
Ethers	No effect
Ketones	No effect
Aliphatic hydrocarbons	No effect
Motor oil	No effect
Aromatic hydrocarbons	No effect
Toluene	No effect
Unleaded petrol	No effect
Dot 3 brake fluid	No effect
Chlorinated hydrocarbons	Moderate effect
Trichloroethylene	Moderate effect

Watertight applications

Thanks to the watertight properties of HP 3D High Reusability PA 12 the printer parts have the following advantages when they are used as fluid vessels replacing other traditional technologies:

Ducts	Deposits	Waterproof covers
• **Unification** of different ducts together • **Efficiency improvement** by designing geometries not possible with other technologies • **Fluid tightness** without any post-processing	• **Optimization** of product space by designing geometries not possible with other technologies • **Any geometry** can work for fluids at low pressure • **Fluid tightness** without any post-processing	• **Customization and personalization** of design • **Waterproofness** without any post-processing
		

Watertightness test characterization

Leakage test results

The leakage test has been performed to determine the possibility of leaks and pressure losses of HP MJF parts working with a fluid under pressure.

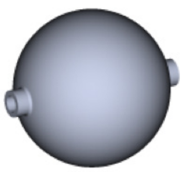
The water is introduced into the different test specimens at a specific pressure and is left for a period of 7 hours. During that time, the specimens are working under a constant pressure, which is compensate in case of the material deformation. The temperature used to performed the test is 25°C.

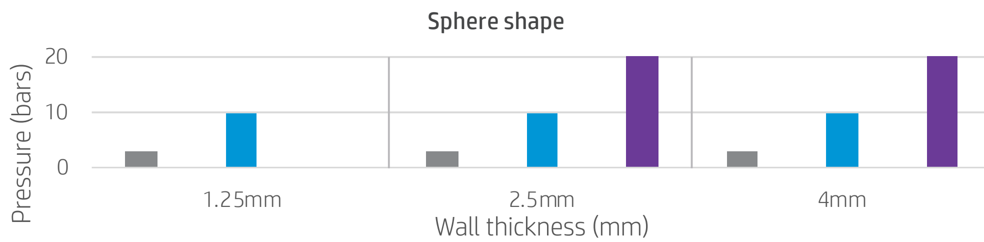
Wall thickness analysis

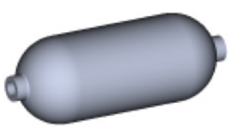
The watertightness characterization test has been performed using three different wall thicknesses. These have been selected due to their wide use in fluid-vessel components: 1.25 mm, 2.5 mm, and 4 mm.

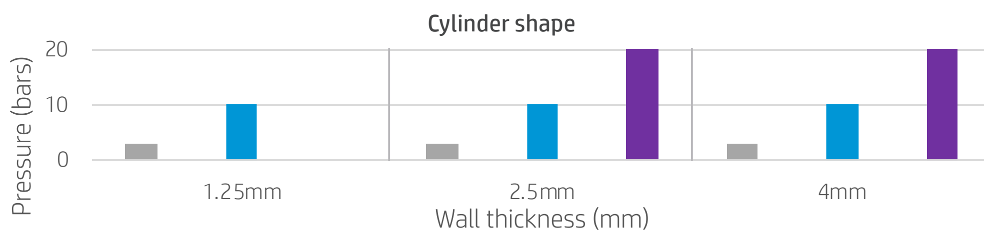
The behavior of the parts with different wall thicknesses under different pressures will identify the best wall thickness depending on the circumstance. From the test results, the recommended values obtained are:

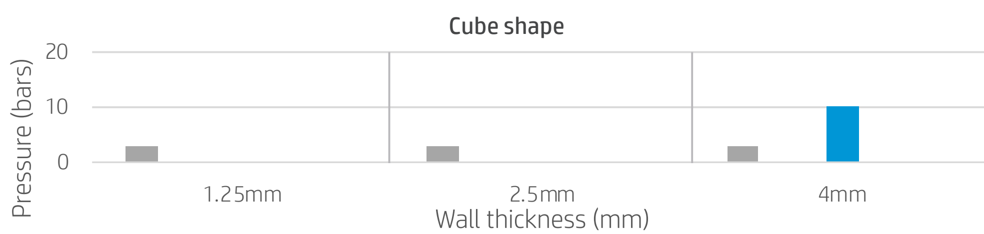
Wall thickness	3 bar	10 bar	20 bar
1.25 mm	Recommended	Not recommended	Not recommended
2.5 mm	Recommended	Recommended	Not recommended
4 mm	Recommended	Recommended	Recommended











Vessel shape analysis

The watertightness characterization test has been performed using three different shaped vessels that simulate the different geometries used in pipelines or deposits that could contain water.

The best shape to work with fluids under pressure is a sphere, because the pressure is better distributed and there are no flat surfaces, which will deform and break easier. Therefore, **it is recommended to design fluid vessels as close to a spherical shape as possible,** because this will help to withstand higher pressures.

The cubic deposits could work only under low pressure, as its geometry is more prone to adverse effects when under higher pressure.

Vessel shape	3 bar	10 bar	20 bar
Spherical	Recommended	Recommended	Recommended
Cylindrical	Recommended	Recommended	Recommended
Cubic	Not recommended	Break	Break

Vessel deformation impact under pressure

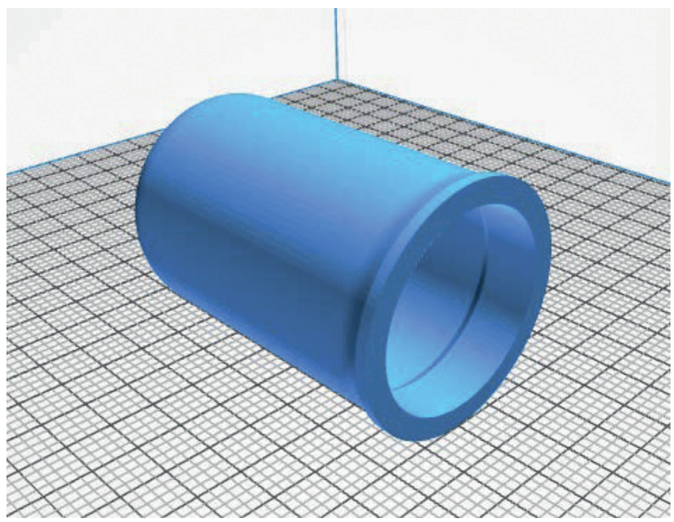
Water is an incompressible fluid. Thus, when it is introduced into a vessel under pressure, small variations in the vessel volume will imply higher variations in water pressure.

HP 3D High Reusability PA 12, like other plastics, deforms when it is used as a container. If this plastic is used with incompressible fluids such as water, the initial deformation will imply a variation in the vessel pressure. This effect is commonly compensated through the pump, which can keep the pressure in the system constant, if needed. However, to keep the part working under a constant pressure, that pressure needs to be below its creep limit, to make sure the part deforms and keeps stabilized in a certain deformation for a long period of time.

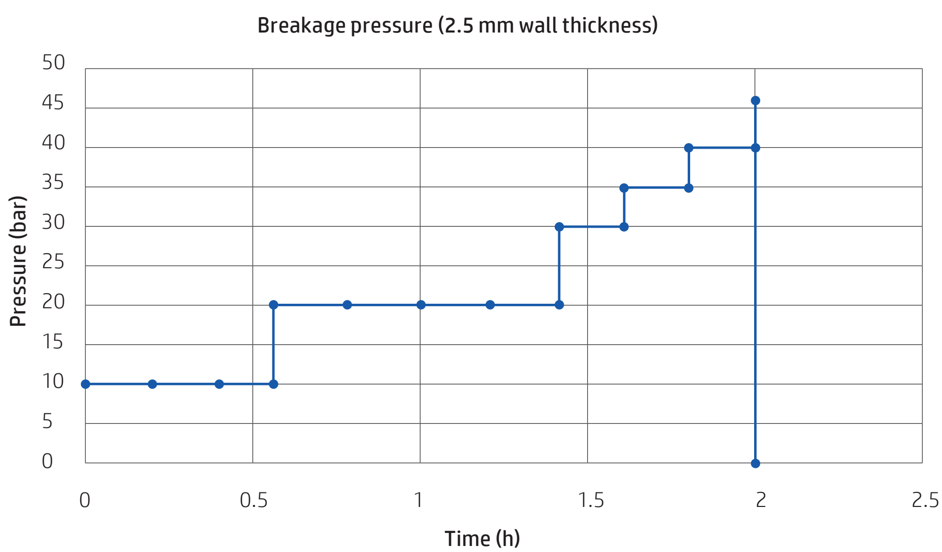
Breakage test results

The breakage test measures the maximum pressure a sample can withstand before it breaks.

These preliminary results were achieved by a customer who used a test sample with 2.5 mm wall thickness (see picture below):



The sample reached 45.9 bar without breaking, as shown in the following graph:



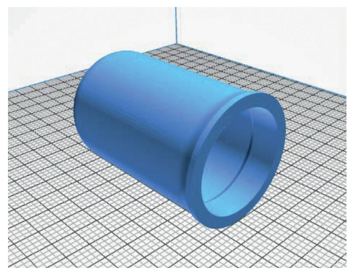
Comparison with other technologies

The breakage test has also been performed with other materials in order to benchmark the performance of printed parts using HP Multi Jet Fusion technology compared to competitors.

Parts printed with HP Multi Jet Fusion technology can withstand similar pressures to Selective laser sintering (SLS), and higher pressures versus other technologies, such as Stereolithography (SLA) or Material Jetting.

Machine	Technology	Material	Temperature	Pressure resistance (wall thickness 2.5 mm)			
				10 bar	20 bar	30 bar	Broken at
Objet Connex500	Material Jetting	Photopolymer Vero Clear	30° C	✓	✓	✓	40 bar
ProJet 3500 Max	Material Jetting	VisiJet (Crystal) SR200	30° C	✓	✓	✓	30 bar
ProJet 6000	SLA	VisiJet Tough	30° C	✓	✓	0	25 bar
ProJet 6000	SLA	VisiJet Hi-Temp	60° C	✓	✓	✓	30 bar
EOS FORMIGA P 100	SLS	PA2200	30° C	✓	✓	✓	45 bar
HP Jet Fusion 3D 4200	SLS	PA12	30° C	✓	✓	✓	45 bar

The benchmark test has been done with the same sample of 2.5 mm thickness:



Chemical resistance

HP 3D High Reusability PA 12 has high chemical resistance to a wide variety of fluids commonly used in the industry. In the table below, the main groups of fluids that could be used with fluid vessels using this material are listed:

Fluid	Chemical behavior
Diluted alkalis	No effect
Concentrated alkalis	No effect
Hot water	Moderate effect
Chlorine salts	No effect
Alcohol	No effect
Esters	No effect
Ethers	No effect
Ketones	No effect
Aliphatic hydrocarbons	No effect
Motor oil	No effect
Aromatic hydrocarbons	No effect
Toluene	No effect
Unleaded petrol	No effect
Dot 3 brake fluid	No effect
Chlorinated hydrocarbons	Moderate effect
Trichloroethylene	Moderate effect

Annex 1. Test procedure

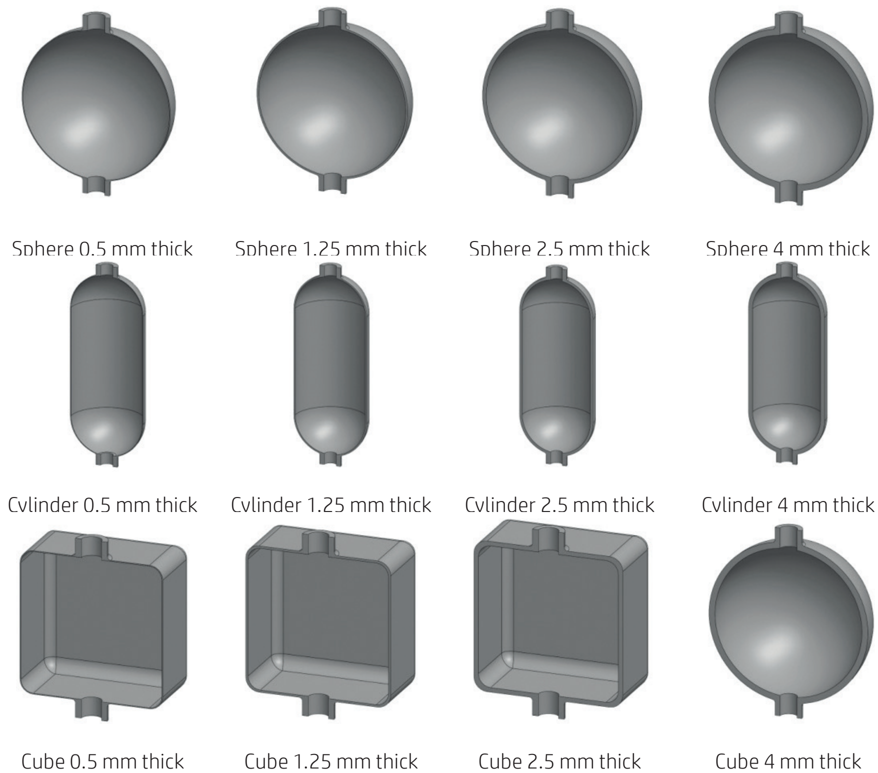
This section describes the equipment used for the performance of the tests and the test setup.

Test specimens

The following table shows the types of specimens and the geometries selected for testing in order to simulate fluid ducts and containers under pressure:

	Sphere	Cylinder	Cube
Ø [mm]	Ø98.5	Ø66 x 100	79.5
R [dm]	0.4925	0.333	0.795
V [L]	0.50	0.50	0.50

Geometry of the test specimens (inner dimensions)



CAD model of the test specimens, with the different wall thicknesses

Equipment

The following images show the components used and their assembly in order to test the specimens under pressure, and avoid leakage of the connectors:

Connectors used for the tightness tests

A mechanical pressure instrument (pressure gauge) is used to measure the pressure on each specimen in line and control the pressure loss on the inside.

A testing pump for the pressure testing of fluid lines and containers is used in order to pump water into the test specimens and reach the desired pressure.

Pressure gauge

Example of an assembled specimen ready to be tested

Test setup

Specimens are initially purged with water in order to extract the air completely from the interior. Then the outlet valve is closed, and pressure is increased with the pump. When the desired pressure is reached, the inlet valve is closed and the specimen is isolated during the duration of the test.

Procedure and setup of the test and the specimens

Tests performed

The first set of experiments executed corresponds to tests of the DoE, showed in the following table:

Test	Fluid	Shape	Pressure [bar]	Wall thickness [mm]	Temperature [°C]	79Experiment ID
Leakage	water	1	3	1.25	25	51
Leakage	water	2	3	1.25	25	52
Leakage	water	3	3	1.25	25	53
Leakage	water	1	3	2.5	25	54
Leakage	water	2	3	2.5	25	55
Leakage	water	3	3	2.5	25	56
Leakage	water	1	3	4	25	57
Leakage	water	2	3	4	25	58
Leakage	water	3	3	4	25	59
Leakage	water	1	10	1.25	25	60
Leakage	water	2	10	1.25	25	61
Leakage	water	3	10	1.25	25	62
Leakage	water	1	10	2.5	25	63
Leakage	water	2	10	2.5	25	64
Leakage	water	3	10	2.5	25	65
Leakage	water	1	10	4	25	66
Leakage	water	2	10	4	25	67
Leakage	water	3	10	4	25	68
Leakage	water	1	20	1.25	25	69
Leakage	water	2	20	1.25	25	70
Leakage	water	3	20	1.25	25	71
Leakage	water	1	20	2.5	25	72
Leakage	water	2	20	2.5	25	73
Leakage	water	3	20	2.5	25	74
Leakage	water	1	20	4	25	75
Leakage	water	2	20	4	25	76
Leakage	water	3	20	4	25	77

Experiments executed on this first delivery

Learn more about HP Multi Jet Fusion technology at

hp.com/go/3DPrint

Connect with an HP 3D Printing expert or sign up for the latest news about HP Jet Fusion 3D Printing:

hp.com/go/3Dcontactus

© Copyright 2018 HP Development Company, L.P.

The information contained herein is subject to change without notice The information contained herein is provided for information purposes only. The only terms and conditions governing the sale of HP 3D printer solutions are those set forth in a written sales agreement. The only warranties for HP products and services are set forth in the express warranty statements accompanying such products and services. Nothing herein should be construed as constituting an additional warranty or additional binding terms and conditions. HP shall not be liable for technical or editorial errors or omissions contained herein and the information herein is subject to change without notice.

4AA7-2720ENW, November 2018