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Date: January 2018

Status: Non-confidential

Subject: Tips and info for building with DuraForm® ProX™ HST Engineered Thermoplastic on ProX™ SLS® systems

DuraForm ProX HST is a fiber filled engineered PA12 based production plastic for use in 3D Systems' ProX SLS systems. DuraForm ProX HST offers high strength, stiffness and elevated temperature resistance (higher HDT at the higher load) when used on the ProX SLS systems. Parts printed using DuraForm ProX HST exhibit anisotropy based on the orientation (different mechanical properties in X & Y orientations).

DuraForm ProX HST is available in three modes, Standard Production (SP) Mode, High Production (HP) Mode, and Advanced Mode. Material configuration files for these modes are offered by 3D Systems. The process settings in the SP configuration files have been optimized to provide a good starting point to operate while using this mode. Process settings for the HP configuration files offer faster processing for higher throughput. Advanced configurations offer more processing latitude for advanced users. SP Mode is the default configuration and the recommended mode by 3D Systems.

The material process parameter set points may vary slightly from machine to machine, due to differences in material conditions and thermal sensors. As a result, the process parameters (more specifically the temperature set points) may need to be adjusted slightly from the defaults. An offline IR sensor calibration is required before using a material for the first time.

Below are the important pieces of information to know in order to build successfully with DuraForm ProX HST on a ProX SLS system. For more details about this material, please refer to the DuraForm ProX HST material guide and for more details about the ProX SLS system, please refer to the ProX SLS user guide.

1. **Hardware Modifications:** Printing DuraForm ProX HST plastic material will require some components in the printer.

Counter Rotating Roller Upgrade: An upgrade to the Counter-Rotating Roller is required in order to successfully print with DuraForm ProX HST. Please contact your 3D Systems field service representative for more information upgrade. This upgrade is critical on a ProX SLS printer.

- 132782-00, /R ROLLER, TEXTURED, PROX SLS, FRU KIT

MQC Sifter Screen Upgrade: To successfully recycle DuraForm ProX HST Plastic material it is required to upgrade the sifting screen of the sifter in the MQC. Please contact your 3D Systems field service representative for more information about this upgrade.

- 4100-03598 Screen Element, 50TBC, 15 inch Sifter, Bonded, RVM-15E
- 4100-03156 Screen, 402M MESH, 15 inch Sifter Screen, MID-ANGLIA (For European use)
- 77-0119 Screen Element, 50 TBC, 12 inch Sifter Screen

2. **Software version:** DuraForm ProX HST config files are supported with Sinter V6.1 and later versions.

3. **Build Preparation software:** SLS Build Packet Files are created to start a build. A Build Packet File (BPF) contains special instructions that are system and material specific. The initial default parameter values, provided in the DuraForm ProX HST material configuration files, are a good starting place for your initial builds. Modification to parameter values may be recommended based on application or system condition.

For more information,
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4. **Material Configuration files:** LS 6.1 material config files are available for download from the 3D Systems website, InfoCenter.3dsystems.com>ProductionPrinters>SLS. The values in the material configs will be a good starting point for your initial builds with this material.

NOTE: Three material configuration files are offered with DuraForm ProX HST: SP mode, HP mode and Advanced mode; SP mode contains default values for general purpose parts building. HP mode contains values for faster build times and higher production output. Advanced mode allows users to modify values to achieve desired properties. Customers running DuraForm ProX HST may need to optimize certain parameters for their systems.

NOTE: A setting of 5 l/min for N₂ laser window flow is recommended for DuraForm ProX HST material

5. **Properties in X vs Y Orientations:** DuraForm ProX HST is a fiber filled material. The fibers have an aspect ratio greater than 1 (longer in one direction and shorter in the other). Hence, DuraForm ProX HST exhibits varied properties with respect to the direction of alignment of the fibers. In the SLS process, the fibers tend to align with their long axis in the X direction. This causes the X directional properties to be higher than the Y directional properties for this material.
6. **SP vs. HP Mode:** SP mode controls the limits of the ProX SLS system to ensure customer get the performance they desire and removes variability that could occur during the standard print process. The HP mode offers faster processing times for users, reducing total build times by about 25%. Conversely, HP mode results in about a drop in mechanical properties. Parts printed using HP mode also exhibit rougher sidewalls

NOTE: It is the customer's responsibility to validate results such as part quality and mechanical properties at the parameter values they use in Advanced Mode. Also, customers/users should note that 3DSystems Field Service might require the use of the SP mode during troubleshooting issues.

The following table highlights the default process parameter values for the SP and HP print modes

Parameter	DuraForm ProX HST SP	DuraForm ProX HST HP
Part Bed Heater Set Point	168.5°C	168.5°C
Powder Layer Thickness	0.1 mm	0.15 mm
Fill Laser Power	65 W	95 W
Outline Laser Power	20 W	30 W
Scan Spacing	0.20 mm	0.20 mm
Fill Scan Count	1	1
Outline Scan Count	1	1
SinterScan™	1	1

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7. **Shrink and Beam offsets:** The shrinkage of 100% fresh DuraForm ProX HST is slightly higher than that of blended DuraForm ProX HST. You should expect to evaluate and adjust the scale values used to compensate for shrink as the fresh powder ratio in the blend changes. Note that shrinkage may vary slightly based on part geometry. The following table offers the starting values to use for scale and beam offsets. These are the same values as in the material configuration file.

Parameter	DuraForm ProX HST SP	DuraForm ProX HST HP
X scale	1.0115	1.0115
Y scale	1.0254	1.0254
Z scale	1.018	1.018
X Fill offset	0.370 mm	0.370 mm
Y Fill offset	0.330 mm	0.330 mm
X outline offset	0.350 mm	0.350 mm
Y outline offset	0.310 mm	0.310 mm
Z offset	0.076 mm	0.076 mm

8. **Part orientation in the SLS build volume:** There are three primary considerations relative to part orientation.
- Large “blocky” sections or structures are susceptible to distortion (post-build curl). Rotating the .stl file a few degrees about X and/or Y can help to mitigate this distortion. Rotation to 30 degrees is shown to give good properties and less distortion.
 - Start these demanding parts later in the build (at greater Z) after other parts have already been built underneath.
 - Parts with wide flat bottoms are recommended to be oriented by 10 degrees in X and Y to eliminate distortion (i.e. bowing) at the bottom.
9. **LEAN:** Lean is a type of post build distortion. Lean occurs at the boundary of the acceptable build area, where the shrinkage of a part has different rates for different regions. Maintaining the most uniform temperature distribution, by modifying the various Heater Ratios, the Cylinder Heater Set Point, and the Piston Heater Set Point will minimize lean.
10. **Routine maintenance:** Avoid leveling powder while purging the system. Exercise care when removing powder residue from sensitive surfaces. Powder build up should be vacuumed and oily residue should be wiped with a scratch-resistant cloth. Clean the laser window with mild liquid detergent under running warm water, and then clean with ethanol and a dust-free lens wiping tissue. Refer to the ProX SLS user guide and DuraForm ProX HST material guide for more details.

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11. **Material handling:** Follow proper PPE when handling DuraForm ProX HST. This includes safety glasses, protective gloves, and a dust mask. Please refer to the ProX SLS user guide and the DuraForm ProX HST material guide for more details. As always, users should review the recommendation in the product safety datasheets (SDS).

NOTE: Fine dust dispersed in air in sufficient concentrations, and in the presence of an ignition source may become a potential dust explosion hazard. As reference, dust deflagration value (K_{st}) is 79 bar·m/sec for DuraForm ProX PA.

12. **Part Breakout, Powder Recycling & Sifting:** Do not remove the print cake from the process chamber until the part bed temperature is approximately 85°C. Allow parts to continue cooling to 50°C before trying to break them out of the print cake.

After a print, loose material can be sifted and reused in another print. Consistent recycling procedures are important in order to maintain consistent material properties. If recycling procedures are not followed, problems such as variable shrinkages and surface imperfections like "orange peel" may appear,

For the ProX SLS system, the part breakout, powder sifting and powder recycling operations are performed at a station called the Material Quality Control (MQC) System. The MQC is an integral part of the ProX SLS printer.

Remove loose powder surrounding the parts with a brush. Use a combination of part breakout tools and a bead blaster to fully remove the powder adhering to the parts. Sift the loose powder into the used bin of the MQC System. Discard any hard, chunky powder and the powder directly surrounding the parts.

The DuraForm ProX HST Plastic material is a very fine blend of small particles. As you run prints, the material is exposed to heat and energy, and as a result the particles in the used powder tend to stick together forming larger particles. You can combat this trend with sifting and blending. Sifting removes undesirable particles from the used powder and blending incorporates new particles of appropriate size. Blending also helps combat the changes in material melt viscosity of the used powder by creating a final blend with uniform material melt viscosity that shows less variance from blend to blend.

13. **Blending Fresh and Used Powder:** The MQC blends the fresh and used powder. The ratio of the fresh to the used powder in a blend can be set for each material and blend. 3D Systems offers a recommended fresh powder ratio to use for each material.

NOTE: For a ProX SLS system, there is no overflow powder to use for a blend unlike the previous generation SLS systems. The overflow powder is recirculated back into the feed hopper during the print process and is ultimately consumed for the print process.

The MQC initiates a blend cycle when it has enough material to blend a total of about 40 liters. For example, at a 75% fresh powder ratio, it requires about 30 liters in the fresh bin and about 10 liters in the used bin in order to initiate a new blend cycle. At any particular fresh powder ratio setting, the minimum volumes of fresh and used powder required to initiate a

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blend are displayed on the MQC home screen. Please refer to the respective ProX SLS System user guides for more information on the MQC.

The default fresh powder ratio setting for DuraForm ProX HST material is 75%.

NOTE: Approximately 0.86 Kgs (1.5 liters) of blended powder (fresh + used) is required for every 10 mm of z- height (please include warmup, build, and cooldown heights for calculation). This number holds true when the volume percentage of parts in a build is about 8%. For builds with higher part volume percentage a larger quantity of powder will be required. The Information tab in the build preparation software also provides the approximate volume of powder required to complete a build.

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