# Customer Information Bulletin

CIB

CIB#: CIB00242
Date: May 2022
Status: Non-confidential

**Subject: Tips and info for building with DuraForm® PAx Engineered Thermoplastic on SLS® systems**

**DuraForm PAx** is an engineered production plastic for use in 3D Systems' SLS systems (SLS 380, SLS ProX 500, ProX 6100, sPro60) and other non-3D Systems external SLS platforms. DuraForm PAx material offers comparable strength and superior elongation to existing nylon 12 and nylon 11 SLS materials on the market. It offers very high recyclability while maintaining the same mechanical properties and good surface finish and part quality with the higher recycled material blend ratios. Additionally, this powder offers good processability, easy break-out and sifting on all SLS platforms.

DuraForm PAx is available in Standard Production (SP) Mode and Advanced Mode. Material configuration files for SP mode is offered by 3D Systems. The process settings in the SP configuration files have been optimized to provide a good starting point. Process settings for the Advanced configuration files offer more processing latitude for advanced users. The material process parameter set points may vary slightly from machine to machine due to differences in the machines maintenance condition, installed location, environmental conditions and thermal sensors. As a result, some of the process parameters may need slight adjustments from the defaults for optimal results. Part bed temperature may need to be adjusted depending on platform age and material recycling ratio and it is always recommended to follow best practices when using recycled powder (see section 11. Part Breakout, Powder Recycling & Sifting and section 12. Blending Fresh & Used Powder). If using this powder on an external, non-3D Systems SLS platform, please review the parameters in this bulletin in sections 5 & 6 carefully to make adjustments that will effectively output the same process settings on your SLS system.

**For SLS printing in general, printer routine maintenance and cleaning are critical for good quality and consistent builds. The laser window and chamber interior must be cleaned after every build; filters need to be checked weekly to prevent excessive dust build up. Periodically check status of black body (clean the black body after every build is if there is no protective cover (ECO) installed. The cover is included in all SLS 380 units).**

This bulletin provides the most important information to build successfully with DuraForm PAx. The sections are in chronological order of getting started, build setup (information about hardware and software requirements), process parameters specific to this material and finally material handling and break-out instructions for best results. For best mechanical properties, especially % elongation at break, see section 13 on Mechanical Properties. Please note, for SLS printing in general, the hardware maintenance status also plays a key role in printing good parts. Please refer to the SLS platform user guide for details about the system operation and maintenance.





For more information, contact 3D Systems' Customer Hotline at (800) 793-3669, or contact your local account representative.

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1. **Hardware Requirements:** DuraForm PAx material is designed for printing on SLS platforms. 3D Systems SLS platforms are not required but recommended for ease of use. The parameters recommended in the material configuration files and this bulletin are best suited for 3D Systems hardware and any other non-3D Systems hardware may require significant adjustments to the process parameters.

2. **Software Requirement**: DuraForm PAx configuration files are supported on various 3D Systems SLS platforms. Below is a table showing the software version and patch requirements (material specific file import) for each platform type. Please contact your 3D Systems service representative for patch files and more information if needed.

| Platform | Sinter Version | Sprint Version | Sprint patch required | Sinter patch required |
|---|---|---|---|---|
| SLS 380 | 7.1 or later | 4.0.0 | yes | yes |
| | | 4.1.0 | no | yes |
| ProX 6100 | 6.3.527 | 3.1 | yes | yes |
| | 7.1 or later | 4.0.0 | yes | yes |
| | | 4.1.0 | no | yes |
| ProX 500 | 6.3.527 | n/a | n/a | yes |
| | 7.1 or later | n/a | n/a | yes |
| sPro 60 | 5.2 | n/a | n/a | yes |

3. **Build Preparation Software**: SLS Build Packet Files are created in the build preparation software. A Build Packet File (BPF) contains special instructions that are system and material specific. The initial default parameter values, provided in the DuraForm PAx 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 finer features and ability to achieve gaps in moveable sections, it may be necessary to adjust the fill and outline laser offset values. Also, for DuraForm PAx material, the CAD file preparation may require higher gap allowances compared to most typical PA12 material file preparations.

4. **Material Configuration Files**: The material configuration files offered for DuraForm PAx are SP Mode and Advanced Mode. SP mode contains the default values for general purpose part building. The material configuration file offers the recommended parameters. The values in the material configuration files will be a good starting point for initial builds; however, some customers running DuraForm PAx may need to optimize certain parameters for their systems. Please monitor initial builds closely and modify part bed temperature as needed (see section 8).

5. **SP Mode vs. Advanced Mode material configurations**: SP mode controls the limits of the SLS system to ensure customer gets the performance expected by default and removes variability that could occur during the print process. The Advanced mode offers more processing latitude for advanced users and increases the allowed range for many of the parameter values. The following table highlights the default process parameter values for the SP print mode for the 3D Systems SLS platforms:

| Parameter | sPro60 | ProX SLS 500/6100 | SLS 380 |
|---|---|---|---|
| Part Bed Heater Set Point | 123°C - 121 °C (ramp down over first 30mm) | 116°C - 114 °C (ramp down over first 60mm) | 112°C |
| Powder Layer Thickness | 0.1 mm | 0.1 mm | 0.1 mm |
| Fill Laser Power | 40 W | 46 W | 44 W |
| Outline Laser Power | 13 W | 16 W | 16 W |
| Scan Spacing | 0.25 mm | 0.2 mm | 0.2mm |
| Fill Scan Count | 2 | 2 | 2 |
| Outline Scan Count | 1 | 1 | 1 |
| SinterScan™ | 1 | 1 | 1 |
| Fill Scan Speed | 12 m/s | 12 m/s | 12 m/s |

**NOTE:** A setting of 5 L/min for N2 laser window flow is recommended. Please verify and adjust flow to the recommended setting.

**NOTE**: The online PAx technical specification values report performance of builds with the parameters above and 30% fresh powder blend ratio (with supplemental data available for 40% and 50% fresh powder blend ratios). It is the customer's responsibility to validate part quality and mechanical properties for any custom parameters and blend ratios used with Advanced Mode.

**NOTE**: Recycled blends of DuraForm PAx are processed approximately 2°C higher than 100% fresh powder and it is recommended that the setpoint is lowered when initially printing with 100% fresh powder if no used powder is available for blending.

**NOTE**: The preheat powder pick-up position (next feed dose) is placed directly next to the piston boundary in the SLS 380 platforms by default in the SP and Advanced DuraForm PAx material configuration files. This is to ensure optimal powder heating prior to the next layer and minimize temperature fluctuations layer to layer. The pick-up position is illustrated in the image below to show the default position.

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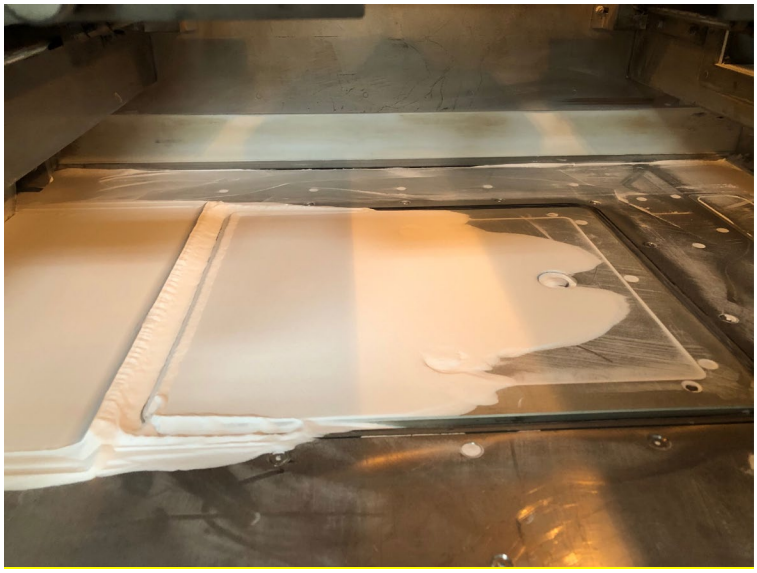

*The next powder dose (preheat pick-up position) pictured here in the print chamber for the SLS 380 DuraForm PAx material configuration.*

6. **Shrink and Beam offsets**: The best optimal shrink and beam offsets are printer and parameter dependent. Once you have established the best build parameters for your application (recycling ratio and printer thermal settings) it is highly recommended to print a scale part (pyramid .stl available on the Infocenter) and follow the steps in the scale and offset wizard. 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 shrink rate may vary slightly based on part geometry. The following table offers the starting values to use for scale and beam offsets for 30% fresh powder blend and default parameters mentioned in section 5. These are the same values as in the material configuration files.

| Parameter | DuraForm PAx 30% Fresh |
|---|---|
| X scale | 1.024 |
| Y scale | 1.024 |
| Z scale | 1.012 -1.181E-5z |
| X Fill offset | 0.292mm |
| Y Fill offset | 0.292mm |
| X outline offset | 0.267mm |
| Y outline offset | 0.267mm |

7. **Part Placement and Orientation in the SLS build volume**:
   - Please ensure parts are not combined or grouped before building as this will alter the scanning pattern.
   - Large "blocky" sections or structures are susceptible to growth. Rotating the .stl file about X and/or Y, when possible, can help to mitigate this distortion when used to minimize cross-sections on a per layer basis. Use the *View* application, and Clipping function in the Z Axis to identify large cross-sections. Please refer to sections "Setting Up a Print" and "Part Placement and Orientation Guidelines" in the SLS DuraForm ProX PA material guide for more details on general setup for SLS printing. If not possible to change the orientation, see section 8 for adjusting laser settings for parts with large cross-sections if there are concerns with part quality and fine features after printing.
   - Start these demanding parts later in the build (at greater Z) after other parts have been built.
   - Parts with wide flat bottoms are recommended to be oriented by a 15-degree angle in X and Y to eliminate distortion in flat sections and help reduce layer time (see section 8).
   - When available, use the *Estimate* application in 3D Sprint build preparation software to identify regions with high layer times and make adjustments to part placement and orientation to minimize layer times. Please read the section "Cross-sections" and build preparation tips in the DuraForm ProX PA material guide for best practices on setting up SLS builds.

8. **Printability and Part Quality:** This section covers some of the most common part quality challenges that may occur while printing with DuraForm PAx material. Outlined are the prevention and troubleshooting of these potential issues. For general information on solving problems during SLS printing and identifying and resolving defects on parts, please refer to the DuraForm ProX PA Material Guide.

   - Part placement and packing density may affect part quality during builds with DuraForm PAx. Parts placed too close together (recommended minimum distance 8mm in X and Y, and 5mm in Z) may lead to local excessive thermal build-up and banding due to uneven shrinkage on side walls (see image).
   - To achieve gaps in moveable sections, it may be necessary to increase the fill and outline laser offset values
   - To reproduce small features it may necessary to decrease the fill and outline laser offset values. Use View Slice in 3D Sprint to evaluate reproduction at current laser offset settings.

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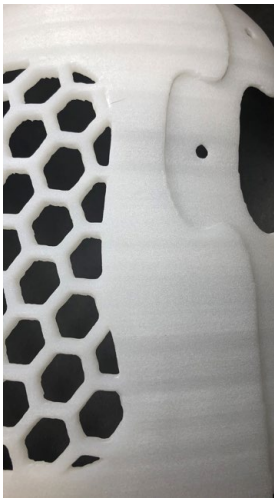

*Example of banding on side-walls*

- High packing density is not recommended for PAx material due to the possibility of excessive long layer times (> 45s). The heaters may turn off for a long time due to high scan times, leading to part quality and property variation. Additionally, high variability in the layer time due to differences in scan time between layers is not recommended and may lead to the banding and side-wall defects, as mentioned above and shown in the image, due to differences in shrinkage. For best part quality, please ensure scanning cross-sectional area (scan time) is similar between layers throughout the build and total layer times are less than 40 seconds. See section 7 in this bulletin and the DuraForm ProX PA Material Guide section on "Part Placement and Orientation Guidelines" for more information on best practices for build setup for SLS printing.
- Growth can occur as material sinters on the part, blurring features and altering part dimensions. This may occur during PAx printing for medium to larger cross-sections. Please reduce laser power and increase scan spacing from the recommended settings and continue to reduce incrementally as needed to achieve desired features. Please note that there may be a compromise between feature quality and mechanical properties if the laser fill settings are significantly lower than those mentioned in section 5 of this bulletin.
- Part bed setpoint may need to be adjusted to prevent printability challenges. If the part bed temperature is getting too hot, there will be evidence of roughening on the print bed as powder is laid and stickiness on the roller. This may start to lead to part shifting and dragging every time the roller passes. Part shifting and dragging may also occur if the part bed is too cold and the parts are curling. For PAx material, a part bed temperature setpoint ramp down may be necessary to avoid curling at the beginning of the build and stickiness later in the build. A gradual temperature ramp of lowering 2°C over 60mm is a recommended

ramp and is included in the material configuration files for 3D Systems platforms. Please adjust as needed to best accommodate your SLS system for non-3D Systems platforms.

9. **Routine Maintenance**: Please conduct routine maintenance on your selected print platform according to user guidelines for the best system performance and part quality. Exercise care when removing powder residue from sensitive surfaces. Powder build-up should be vacuum cleaned, and oily residue should be wiped with alcohol on scratch-resistant cloth. Clean laser window with ethanol and a dust-free lens wiping tissue. Refer to the appropriate user guide for more details. Clean the black body with isopropyl alcohol wet lens wipes to remove powder from its surface once every 450mm of build height for those SLS platforms that do not have a protective cover for the black body. If the SLS system has a protective cover, check the surface of the black body weekly and clean surface as needed.

10. **Material Handling**: Follow proper PPE when handling DuraForm PAx material. This includes safety glasses, protective gloves, and a dust mask. Please use material directly from the packaged container and transfer to the printer or MQC (if applicable) when it is ready to for use. Any recovered part cake material is recommended to be stored in a dry, sealed bag or container if not being placed in a MQC.

**NOTE:** Fine dust dispersed in air in sufficient concentrations, and in the presence of an ignition source may become a potential dust explosion hazard. The dust deflagration value ($K_{st}$) is **114** bar·m/sec.

11. **Part Breakout, Powder Recycling & Sifting**: DuraForm PAx powder is highly recyclable, up to 30% refresh rate (30% fresh, 70% used powder) without any loss in mechanical properties and part quality if the best practices of powder recycling mentioned below. For SLS systems that have an overflow material collected separately, the used powder can be a combination of part cake and overflow with any ratio of each (while maintaining the same refresh rate) and will yield consistent results. Additionally, DuraForm PAx material has a relatively faster and easier break-out due to reaching temperatures appropriate for break-out more quickly and having softer part cake compared to most other common SLS materials. The default softer part cake allows easier and faster post-processing. Do not remove the part cake from the process chamber until the part bed surface temperature is below 80°C and do not handle the part cake until the internal temperature is below 50°C for safety reasons.

After a build, loose powder can be sifted and reused in another print. DO NOT reuse any powder that is directly adhering to the parts after removal from the part cake. Brush the powder layer closest to the surface of the parts away and discard. Keep this layer of powder separate from the powder being intended for reuse. Additionally, discard any hard, chunky powder and clumps in the part cake and DO NOT reuse. The powder can be blended lower than the recommended refresh rate of 30% (allowable refresh rate is up to 10% fresh, 90% used powder (combination of overflow and part cake, or part cake only)). Use a combination of part breakout tools and a bead blaster to fully remove the powder adhering to the parts. Consistent and best recycling practices are important to

maintain consistent material properties and part quality. If recycling procedures are not followed, problems such as variable shrinkages and surface imperfections may appear.

As other commercial SLS powder materials, DuraForm PAx 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 agglomerate 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.

For users not blending automatically with an MQC, please blend powder with the same method and 1.5 times the duration of DuraForm PA powder blending (1.5 times the duration of typical PA12 powder blending).

12. **Blending Fresh and Used Powder**: 3D Systems offers a recommended fresh-to-used powder ratio for each material. Depending on the SLS system, overflow powder will not be automatically recirculated and will be available at the end of the build in addition to used powder. For DuraForm PAx material, the most important factor for part quality is that the blend ratio is kept consistent after establishing optimal parameters for your system. Based on your system, use up to all used powder in addition to fresh powder or a consistent ratio of used powder and overflow powder in addition to fresh powder. Please establish and use consistent method of blending powder if being done outside of an Material Quality Control (MQC) System.

For SLS systems that are used along with the MQC, blending is handled automatically. For any particular fresh powder ratio, the minimum volume of fresh and used powder required to initiate a blend is displayed on the MQC home screen. Please refer to the respective ProX SLS User Guide and MQC User Guide for more information.

**The default fresh powder ratio setting for DuraForm PAx material is 30%.**

The PAx SP and Advanced print modes are optimized for 30%-50% fresh blend ratio. If using 100% fresh, the part bed temperature may need to be lowered 1-2˚C for improved printability to avoid stickiness.

For the 3D Systems ProX SLS systems, the part breakout, powder sifting and powder recycling operations are performed at the MQC station which is an integral part of the ProX SLS printer.

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

**NOTE:** Approximately 0.53 Kgs (1.17 liters) of powder is required for every 10 mm of z-height (please remember to include warm-up, build, and cool-down heights in total build height calculation). This number holds true when

the volume percentage of parts in a build is around 15%. The *Estimate* application in the 3D Sprint build preparation software (for available platforms) also provides the approximate time and volume of powder required to complete a build.

13. **Mechanical Properties:** Mentioned below are some of the most notable factors that will affect mechanical properties of DuraForm PAx parts. Any changes to build parameters, part parameters and powder blend ratios may lead to changes in mechanical properties and part quality. Please note the information in this section while setting up any custom build styles in Advanced Mode or builds on non-3D Systems printers.

- PAx thermoplastic polymer, unlike most other common nylon SLS materials, has a recovery period post-printing to regain full tensile elongation. The parts are typically most rigid immediately after post-processing and you may experience some stiffness in sections such as living hinges. The elongation recovers after 2-3 days of storage and we highly recommend conditioning parts, when possible, at the ASTM recommended standards for a minimum of 40 hours at 23 °C, 50% RH after breakout before use. When it's not possible to condition, we recommend storing parts for a minimum of 48 hours before use. This will ensure the properties have plateaued after printing, with an increase in elongation up to 100% in all printing orientations.
- The 24hr water absorption is 0.74% (for comparison DuraForm ProX PA has 24hr water absorption of 0.65%).
- The part build orientation affects the mechanical properties of printed parts due to the inherent anisotropy caused by layer bonding in 3d printing. Components built with DuraForm PAx along the Z-axis show approximately a 90% drop in tensile elongation compared to components built along the XY plane (see table below for mechanical properties based on different build orientations). The tensile strength and modulus are isotropic in all build orientations. Below is a table summarizing the mechanical properties based on build orientation. Please refer to the technical datasheet for more information.

| Duraform PAx | | | | | | |
|---|---|---|---|---|---|---|
| **Solid Material** | | | | | | |
| **Mechanical** | | | | | | |
| **Metric** | **Method** | **Metric** | | | | |
| | | **XY** | **YX** | **XZ** | **ZY** | **Z45** |
| Tensile Strength Ultimate | ASTM D638 Type I | 40 MPa | 38 MPa | 41 MPa | 40 MPa | 39 MPa |
| Tensile Strength at Yield | ASTM D638 Type I | 40 MPa | 38 MPa | 41 MPa | 40 MPa | 39 MPa |
| Tensile Modulus | ASTM D638 Type I | 1300 MPa | 1400 MPa | 1500 MPa | 1400 MPa | 1400 MPa |
| Elongation at Break | ASTM D638 Type I | 282 % | 326.9 % | 31.4 % | 32.8 % | 41.5 % |
| Elongation at Yield | ASTM D638 Type I | 5.5 % | 5.5 % | 5.4 % | 5.9 % | 6.9 % |
| Flex Strength | ASTM D790 | 37 MPa | 32 MPa | 34 MPa | 34 MPa | 32 MPa |
| Flex Modulus | ASTM D790 | 880 MPa | 740 MPa | 820 MPa | 870 MPa | 820 MPa |
| Izod Notched Impact | ASTM D256 | 41 J/m | 36 J/m | 26 J/m | 38 J/m | 32 J/m |
| Izod unnotched impact | ASTM D4812 | Did Not Break | 270 J/m | 280 J/m | 350 J/m | 330 J/m |
| Shore Hardness | ASTM D2240 | 66 D | 65 D | 64 D | 65 D | 65 D |

Mechanical properties based on part build orientation. Parts are tested in the X, Y, Z (ZX and ZY) and angled (Z45) orientations to determine the degree of isotropy within the mechanical properties. Parts tested for the data in this table were printed with 30% fresh-70% used powder blend on the SLS ProX 6100 and SLS 380 platforms.

- The part bed temperature is one of the most significant parameters in the sintering process. The part bed temperature setting is optimal for PAx in the SP and Advanced Mode default configuration parameters.

However, due to the possible machine to machine variations mentioned above, or application part specific requirements, the part bed temperature may need to be slightly adjusted to ensure optimal melt flow, crystallization rate and densification of parts taking place to achieve uniform mechanical properties.

- For DuraForm PAx material, the various blend ratios tested in 30-50% fresh and 100% fresh powder ratios did not have a significant effect on the mechanical properties. However, blends with recycled powder did tend to have better printability compared to 100% fresh powder.
- Part location on the print bed influences mechanical properties of printed parts. Parts placed in the center of the build have shown better mechanical properties compared to parts built close to the edges of the build area.