About Tech Talk

Tech Talk is a series of white papers created by engineers at Mantaro to share our knowledge in different technical areas. With a diverse and progressive set of clients, Mantaro has a rich history of staying at the leading edge of the technology curve. To keep the entire engineering team updated on the latest tools, trends, and technology, Mantaro holds regular meetings where engineers share their findings. Tech Talk captures this wealth of knowledge in the form of white papers which are made available to the general pubic through our website. If you have any questions or comments, please email us at techtalk@mantaro.com.

About Mantaro

Mantaro provides a full range of product development services to our technology clients. Our technical staff comprises highly talented professional engineers with a history of successful product development and innovative design experience. The Mantaro team has many years of industry expertise with leading companies that develop consumer electronics, industrial control systems, telecommunications systems, software applications, semiconductors, test and measurement instrumentation, and transportation systems.

Our team is composed of diverse professional engineers who hold degrees in Electrical Engineering, Computer Science and Mechanical Engineering and includes several holding Masters' degrees. Whether it is designing a new high-speed interface for a client's existing product line or developing a product or system to address a new market opportunity, Mantaro can provide a solution to meet the challenge.

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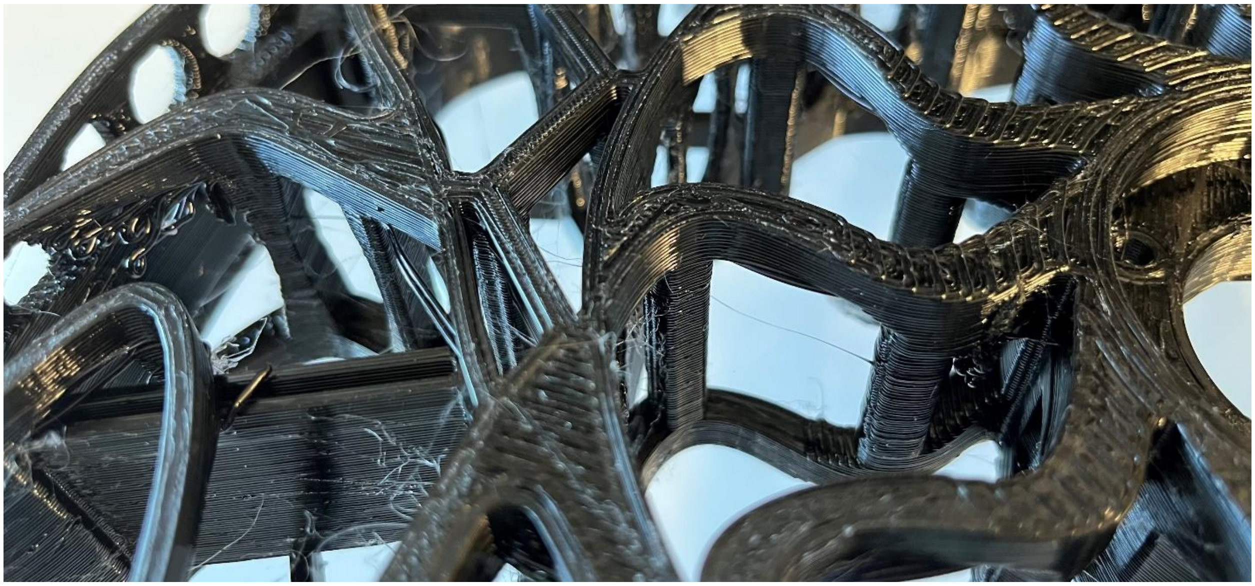
Flexible TPU 3D Printing



Abstract

Printing a complex part with many open voids often requires temporary supports during the printing process to achieve the design goal. However, these supports can be difficult and time consuming or impossible to remove and may make the part unusable. The properties of ThermoPlastic Polyurethane (TPU) allow bridging features to cleanly print up to 1.5 inches unsupported. Careful design can leverage these properties of TPU to create 3D printed parts that leverage complex geometries and internal voids to create light weight, tough, flexible and functional parts without requiring supports.

Introduction

Thermoplastic polyurethane (TPU) typically has a high elastic deformation before plastically deforming. The yield strength of TPU paired with the large elastic deformation zone makes a very tough material that is excellent for living hinges, bumpers and other shock absorbing components. Parts that are 3D printed using TPU filament can be designed to account for expected loads such that they present rigidity and flexibility as the use scenario varies.

Fused Filament Fabrication (FFF) 3D printing allows for the Infill of the part to be some percentage hollow allowing great control of the overall density of the part. Additionally, FFF 3D printing lets the designer create structures that would be difficult and expensive to create using other manufacturing processes. The accessibility and low cost of FFF 3D printing technology creates an operating environment for low-cost design iterations and low volume production. One of the other great properties of TPU is that the layer-on-layer bonding of TPU can be greater than that of other plastics[1].

[1] For example, the tensile strength of 3D fuel Pro PLA is 40 percent weaker (calculated as 1- (xz plane yield strength/xy plane yield strength) * 100%) when loading perpendicular to the bonded layers (*Pro PLA+, Midnight Black, 1.75mm*. 3D. (n.d.).) vs a 3.5 percent reduction for 92A FDM TPU Stratasys filament (*FDM TPU 92A*. Stratasys. (n.d.).).

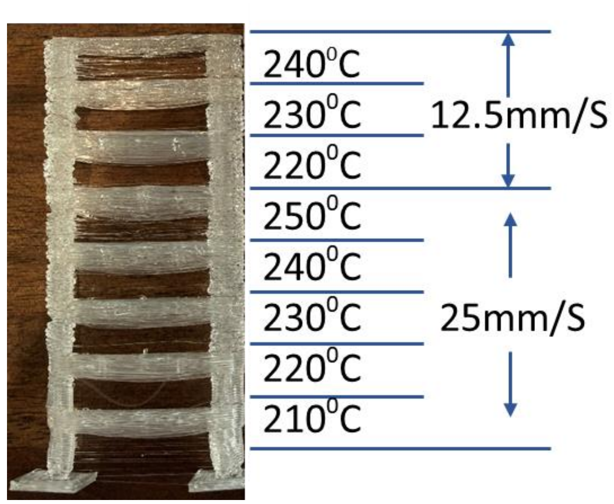
However, when support structures are required for TPU 3D parts with overhangs or internal voids the layer adhesion property results in support structures that are difficult to remove cleanly, therefore designing and printing a structure with no support needed is ideal.

Utilizing bridging capabilities of printing with TPU significantly reduces the time needed for post processing supports out of a model with hard-to-reach internal pockets as well as eliminating the need for secondary support filament. These factors allow for lower cost, quicker turn iterations of components.

Inevitably bridging will be a necessary step for the FFF printing process when designing a hollow TPU structure to get the ideal structural properties and shapes. This paper describes the methods developed at Mantaro

Determining Optimal Print Settings

The material properties of the TPU will vary by brand. Finding the optimal temperature and speed for the TPU brand is a necessary step. Mantaro conducted TPU bridge tests at various speeds and temperatures to determine the settings that best suit the material. This was accomplished by modeling a ladder with the maximum span distance required of the part. The model was sliced and the G-code modified such that each rung of the ladder could be printed at a different temperature and speed. Once printed the ladder could be inspected for the best tradeoff of sag and layer adhesion. Too high a temperature causes filament sag during the print. Too low a temperature causes the layers not to bond.



Once these parameters are known the model can be designed in CAD such that the maximum bridge distance is less is less than that modeled. Mantaro used Autodesk Fusion 360 to create the 3D models. The following guidelines were observed during the design process.

- Avoid overhang angles less than 45 degrees (inverse Tan of rise over run of layer height and overhang material width to prevent unsupported shallow overhangs) e.g. Tan^-1 (0.32 mm layer height/ (0.8 mm nozzle x (1-.6)))
- Keep maximum bridge distance shorter than what provided satisfactory results in the bridge tests. For our setup this was 1.5 inches.
- Straight line bridges with little to no curvature from endpoint to endpoint
- Avoid bridge ends being too slender so that they can easily be grabbed for the bridge, the vertical support should be stable enough to hold its vertical position without shifting as printer moves

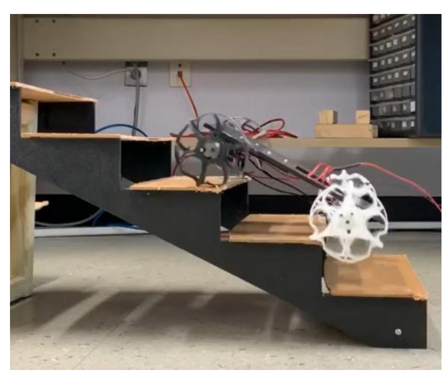
The following print settings for the Sovol 3 direct drive printer were used to print the OceBot Wheel. This is a large part with a diameter of 12 inches.

Print settings:
Printer style: Fused Filament Fabrication (FFF)
Material: TPU 95A Sainsmart
Nozzle size: 0.8 mm brass nozzle
Printer: Soval 3 direct drive 3D printer
Print temperature: 232 deg C
Build plate temperature: 60 deg C
Print speed: 30 mm/s
Sliced in Cura (4.11)

Mantaro case studies for TPU 3D printing

Patent Pending OceBot Wheel

The OceBot is a 4 wheel drive unmanned ground vehicle (UGV). It is designed for surveillance in and around buildings and has custom wheels designed to climb over obstacles and up and down stairs. The OceBot wheel capitalizes on the high flexibility and durability properties of TPU to create a lightweight wheel for rugged applications. In addition to stair climbing the UGV was designed to withstand drops from up to 8 feet. The wheel was carefully designed to use the properties of the TPU material to create rigid and flexible structures into the wheel. Depending on the load these structures will deflect when dropped or stay firm to support climbing.



The first prototypes of the wheels were printed 1/3rd scale and tested on 1/3rd scale obstacles and stairs. Printing at this scale allowed the wheel's features to be printed with standard 3D print settings that did not require supports and yielded parts after minimal print time. However, as we scaled up to full size the wheel was printed with supports on in the slicer. The resulting wheel included a lot of support material that needed to be removed. Unfortunately, some of the support material could not be removed and encumbered the performance of the wheel. We also tried a commercial service to fabricate a set of 4 wheels using Selective Laser Sintering (SLS) 3D Printing. This produced a nice result however it was an expensive and time-consuming process and not amenable to the iterative design and test approach required for the application. We also investigated methods of printing the wheels in parts and fastening them together using adhesive but that was also not viable. Finally, we experimented with the properties of TPU in unsupported bridging applications to determine the limits of that approach. The result is a process for rapidly prototyping and testing concepts in TPU using FFF printing without supports allowing for the design to be economically iterated with the resulting wheels being as light weight as possible and meeting the design goals.

Find out more about the OceBot UGV at: mantaro.com/OceBot

Prototype Enclosure Bumpers

Enclosures designed for rugged applications require tough durable contact points for protecting embedded electronics. Mantaro has used FFF 3D printing of TPU using varying infill and bridging properties to design and iterate prototype wrap around bumpers for rugged application electronic enclosures. TPUs properties of high abrasion resistance and ability to be deflected large percentages without plastically deforming has made it ideal for bumpers on enclosures. When developing small electronic closures that need to dissipate impact over the body, creating a wrap of TPU material to surround the enclosure was found to be an ideal solution. This technique requires printing the TPU structure hollow so that it can be stretched around the assembly. Previously in testing materials for this application Polyjet 3D printing photopolymer (VeroBlackPlus RGD875) process and material were used. This material would degrade overtime in bend locations and fracture with use. While this material and process was great for initial testing the final functionality of the part was hampered by its overall fatigue life. This bend fatigue life is especially critical when designing in features such as removable dust and seal plugs with integrated living hinge leashes.

Find out more about Mantaro's mechanical design capabilities at:
mantaro.com/index.php/mechanical-design

References:

Pro pla+, Midnight Black, 1.75mm. 3D. (n.d.). Retrieved March 15, 2022, from https://www.3dfuel.com/collections/pro-pla/products/pro-pla-midnight-black-1-75mm

FDM TPU 92A. Stratasys. (n.d.). Retrieved March 15, 2022, from https://www.stratasys.com/en/materials/materials-catalog/fdm-materials/tpu-92a