WHITE PAPER

Stress Testing 3D Printed Parts for End-Use Applications

Modern manufacturing theory, tools, and best practices are focused on how to make thousands or millions of identical parts or products at a low cost per unit. Custom and low volume production pose unique challenges that require manufacturers to adapt from typical mass production models. Thanks to the rapid development of technologies and materials over the last decade, additive manufacturing has grown more capable as a true manufacturing tool and can now enable the fabrication of these custom and low volume end-use parts rapidly and cost-efficiently.

This white paper presents Formlabs 3D printing hardware and material solutions for end-use part production. It documents various users' case studies and includes stress testing results to verify the suitability of 3D printing materials for end-use applications.

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formlabs

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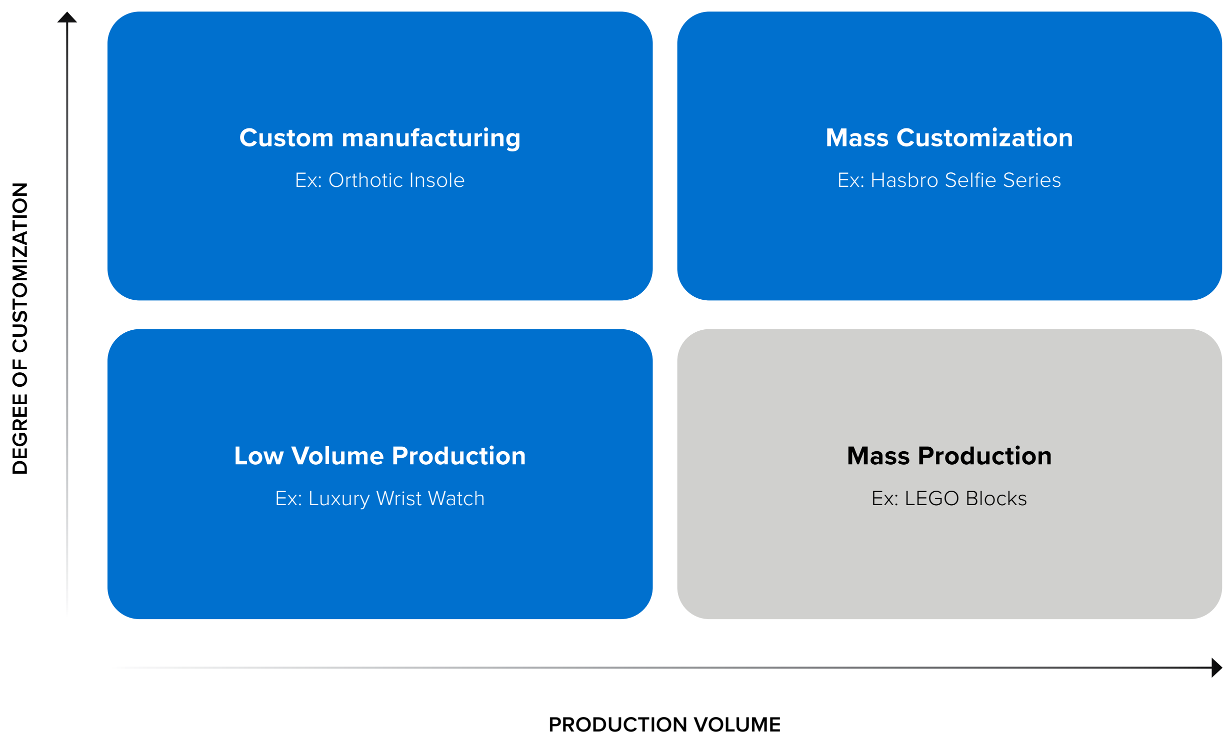
Introduction

LOW VOLUME PRODUCTION AND CUSTOM MANUFACTURING AT SCALE

Today, most manufacturing methods such as molding or forming are based on the concept of mass production: fabricating large quantities of identical goods. While these techniques are extremely cost-efficient for high-volume production (over 10,000 parts), they require standardization, expensive machinery, and tooling that rarely allow for product modifications.

In contrast, the fabrication of items based on unique specifications, or custom manufacturing, is traditionally performed manually in small workshops. Because of the high proportion of manual labor and less efficient tools, this results in a higher cost per part for custom products. For the same reasons, creating large quantities of individually custom-built goods, referred to as mass customization, has seldom been economically viable.



Additive manufacturing (AM), also known as 3D printing, is a powerful tool that offers unique benefits, making it ideal for low volume production, custom manufacturing, and mass customization. In-house 3D printing enables manufacturers to tighten supply chains and shorten lead times with local, on-demand production to meet changing business needs rapidly.

Being a toolless fabrication process, 3D printing presents a few advantages:

- Eliminates excessive tooling costs and often months' long lead times.
- Provides the flexibility to revise products quickly, accelerating time to market.
- Enables customization and offers unprecedented design freedom to build complex parts using organic, latticed, or intricate shapes without any additional costs.

3D printing has been ubiquitous in prototyping and product development for decades. Now, this maturing technology is entering widespread use in manufacturing. In the product development process, manufacturers are already leveraging the flexibility of 3D printing for producing internal tools, such as jigs, fixtures, and other manufacturing aids, or even rapid tooling such as molds for injection molding or thermoforming.

Recent advances in machinery, materials, and software open opportunities for producing high-precision, functional 3D prints that can stand in for end-use parts—parts that are sold to and used by the final customer—empowering businesses to bring innovative products to market and make small and mid-scale manufacturing finally accessible.

WHY 3D PRINT END-USE PARTS?

The drive for innovation, improved quality, and lower costs constantly pressures manufacturers as they seek to remain competitive. In-house 3D printing enhances the production process by improving its flexibility, agility, and ability to quickly scale up to meet demand.

It can be a game changer in many production scenarios, including:

PRODUCT INNOVATION

With 3D printing, designers can push the boundaries of design complexity, optimize structures, and tailor parts at no extra costs to develop unique products that are difficult to manufacture with traditional methods. Companies can rethink the way products are made and explore new business models that bring them closer to their individual customers' needs, such as mass customization.

Hasbro Selfie Series, the first personalized, mass-customized action figures.

BRIDGE MANUFACTURING

Bridge manufacturing is a stage in the product development process that bridges the gap between prototyping and production. Businesses across all industries can leverage 3D printing to quickly and affordably produce smaller batches of parts before transitioning to mass production. They can reduce mass-production risks by using 3D printed pilot runs for product testing, pre-sales, or market validation before committing to expensive tooling for mass production.

Tension Square produces an innovative medical device with 3D printing.

SUPPLY CHAIN RESILIENCE

Global supply chain bottlenecks increase lead times and represent a major threat to new product time-to-market, client satisfaction, and overall competitive advantage. 3D printing can be leveraged for temporary production, to quickly and affordably produce short runs during times of shortage. It allows businesses to reduce their reliance on third-party suppliers, withstand logistics disruptions and geopolitical issues, and answer rapidly to market changes by bringing manufacturing capabilities in-house.

3D printed COVID-19 test swabs produced in response to the global pandemic.

AFTERMARKET PARTS

Aftermarket manufacturers create end-use products that operate as components or additions to an existing product from the original equipment manufacturer (OEM). For these applications, introducing new innovative products while keeping up with OEM's product updates is a major challenge. By eliminating tooling, 3D printing brings the agility needed to adjust aftermarket components on demand, both in design and production.

Aftermarket companies can build complex geometries to improve product performance or tailor products to their customers. 3D printing helps to minimize inventory and ensure continued compatibility through the original equipment manufacturer's updates.

Battle Beaver Customs' Playstation 5 controllers with 3D printed internal parts.

Automotive supplier Brose has been evaluating 3D printing spare part production

SPARE PARTS

When an OEM stops production of a particular product or model, they have to continue to stock thousands of parts to service clients who have legacy products and need replacements or repairs. If the OEM doesn't create and store enough of these spare parts, large groups of customers who still use those discontinued models are often left without solutions. It is difficult for an OEM to calculate exactly how many parts to store—if they overestimate, they have to deal with waste and storage issues, and if they underestimate, buyers become disgruntled.

3D printing spare parts in-house allows manufacturers to shift from a physical to a digital inventory. Only the CAD models are stored to produce on-demand parts and replace a lost or damaged item. Companies can also directly switch their production method to 3D printing to eliminate repair and spare part management. The product is treated as a consumable and replaced on demand.

This solution improves supply chain management, mitigates risks of overproduction, reduces waste, decreases storage costs and time for repair and ultimately ensures customer satisfaction.

How to 3D Print End-Use Parts?

Formlabs SLA 3D printer fleet printing Gillette's customized razor handles.

PRODUCING END-USE PARTS WITH SLA PRINTING

Stereolithography (SLA) 3D printers are great tools to fabricate parts rapidly and at a low cost. They require very limited equipment, and can be seamlessly integrated into any production workflow as they are easy to setup, operate, and maintain.

SLA resin 3D printers use a laser to cure liquid resin into hardened plastic in a process called photopolymerization. SLA parts are isotropic, and have the highest resolution and accuracy, the clearest details, and the smoothest surface finish of all plastic 3D printing technologies. These characteristics can match the aesthetic required for consumer goods, such as figurines and personal care items. Formlabs also offers a portfolio of biocompatible resins to serve the healthcare sector, from dental splints and occlusal guards to medical devices such as COVID-19 test swabs.

A range of engineering SLA materials are also available, with advanced mechanical and thermal properties that enable applications in demanding environments. Formlabs recently released the Polyurethane Resin family, for long-lasting parts that need to withstand repeated functional use such as automotive components or footwear. Additionally, post-processing and finishing methods such as electroplating or coating can be applied to SLA parts to improve material properties and enable long-lasting products.

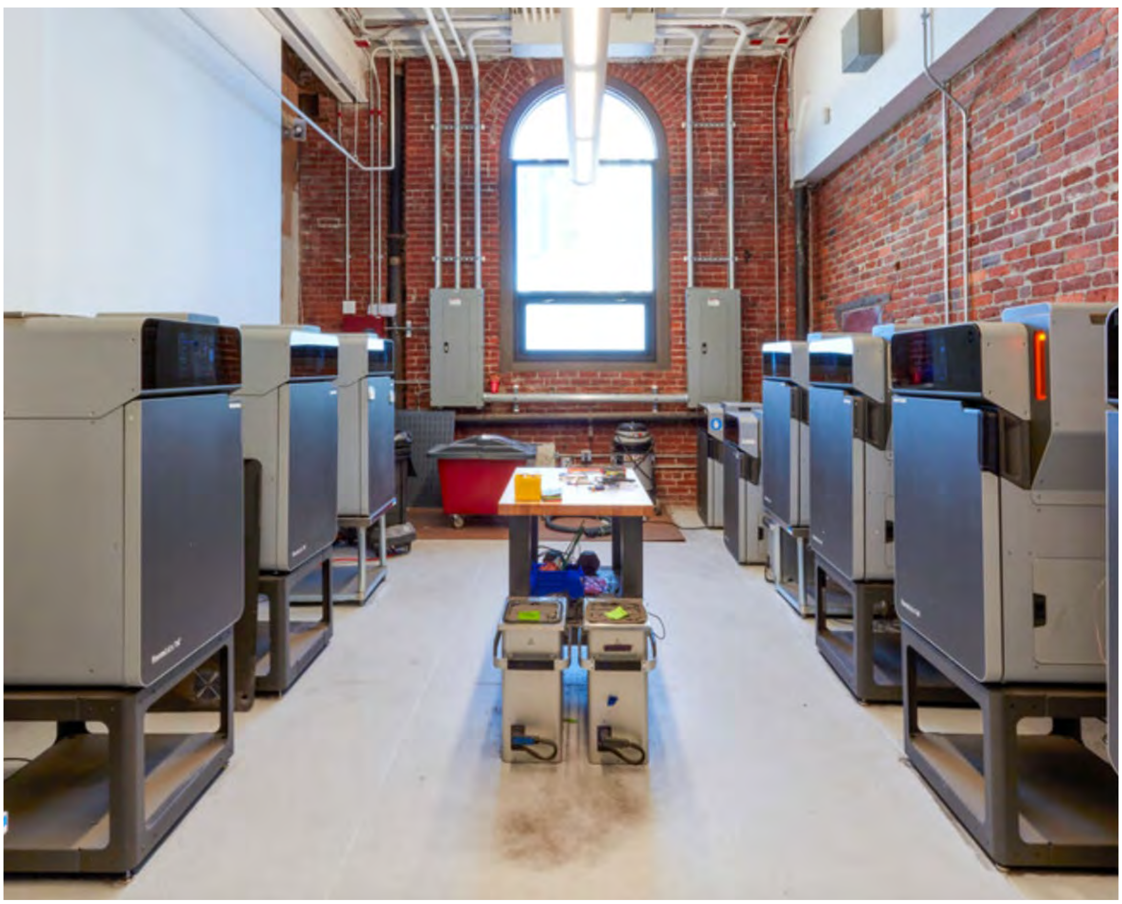
The subsurface automated samples, developed by the National Oceanic and Atmospheric Administration (NOAA), have SLA 3D printed end-caps, sample cartridges, and internal armatures. The parts are watertight and are left underwater for months for coral reef research and monitoring. (image courtesy of NOAA)

PRODUCING END-USE PARTS WITH SLS PRINTING

Selective laser sintering (SLS) is the most popular additive manufacturing technology for industrial applications, trusted by engineers and manufacturers across different industries for its ability to produce strong, functional parts. The combination of low cost per part, high productivity, and established materials makes SLS an ideal choice for producing limited-runs of end-use parts.

While SLA is a resin based-process, SLS 3D printers use a high-powered laser to fuse small particles of polymer powder. The unfused powder supports the parts during printing and eliminates the need for dedicated support structures. This makes SLS ideal for complex geometries, including interlocking links, functional assemblies, and living hinges. Parts produced with SLS printing have excellent mechanical characteristics, with strength resembling that of injection-molded parts.

Formlabs' Fuse Series ecosystem is a compact, contained solution that packs industrial power at a fraction of the cost of traditional SLS 3D printers. Bringing SLS in-house means businesses can control a greater portion of their manufacturing processes. Fuse Series printers are intuitively designed, and have an accessible workflow, allowing companies to integrate them into existing systems seamlessly. The Fuse Sift post-processing unit takes the complexity out of the post-processing stage, and the removable build chamber allows for continuous production, all with minimal labor.



Thanks to its small footprint and affordable price, scaling up with the Fuse Series SLS 3D printers is easy as demand grows.

One of the main advantages of SLS is the materials. SLS 3D printing materials, such as nylon, are already commonly used in the design, engineering, and manufacturing, whether through an injection molding process or additively manufactured. Nylon parts are strong, durable, temperature-resistant, and long-lasting, making them ideal for end-use applications. Nylon is resistant to UV, light, heat, moisture, solvents, temperature, and water. The final parts are impact-resistant and can endure repeated wear and tear. 3D printed nylon parts can also be biocompatible and not sensitizing, which means that they are ready to wear and safe to use in many contexts.

Formlabs offers a variety of SLS powders:

- **Nylon 12 Powder** is a general purpose powder for strong, functional parts with great dimensional accuracy. It is the best fit for most applications including electronic housings, connectors and adapters, or prostheses.
- **Nylon 11 Powder** is a ductile, strong, flexible material for when durability and impact resistance are key. It is the best choice for snaps, clips, hinges, and pliable parts.
- **Nylon 12 GF Powder** is a glass-filled material with enhanced stiffness and thermal stability for demanding industrial environments and for parts ongoing sustained loads and high temperatures.
- **Nylon 11 CF Powder** is a carbon fiber-filled material; it is highly stable and lightweight for optimized stiffness.

Compare material properties of Formlabs SLS 3D printing powders:

MATERIAL	NYLON 12 POWDER	NYLON 11 POWDER	NYLON 12 GF POWDER	NYLON 11 CF POWDER
Ultimate Tensile Strength (X,Y,Z) (MPa)	50 , N/A , N/A	49 , N/A , N/A	38 , N/A , N/A	69 , 52 , 38
Tensile Modulus (MPa)	1850	1600	2800	5300
Elongation at Break (X/Y)	11%	40%	4%	9% / 15%
Elongation at Break (Z)	6%	N/A	3%	5%
Notched Izod (J/m)	32	71	36	74

Those materials can go even further in performance and appearance when paired with advanced post-processing methods. Read our guide to learn about both the basics of post-processing SLS 3D Printed parts and advanced methods such as media blasting, smoothing, coating, coloring and more.

EXAMPLES OF COMPANIES 3D PRINTING END-USE PARTS

Formlabs' community is already producing end-use parts with both the SLA and SLS 3D printing ecosystems. This chapter showcases some of these examples.

Consumer Goods

Part	**Razor Handle**	**Figurine**	**Shoe sole**
Company	Gillette	Hasbro	New Balance
Technology	SLA Custom Resin	SLA Custom Resin	SLA Rebound Resin
Use Case	Mass Customization	Mass customization	Low volume production
Volume of Production	N/A	N/A	1,000 part limited series

Part	**Eyewear**	**Gaming controller parts**	**Mobile phone mount**
Company	Marcus Marienfeld AG	Battle Beaver Customs	Rapid 3D Service
Technology	SLS Nylon 11 Powder	SLS Nylon 12 Powder	SLS Nylon 12 Powder
Use Case	Custom manufacturing	Aftermarket parts	Low volume production
Volume of Production	N/A	N/A	N/A

Automotive, Aerospace and Transportation

Part	**Electroplated hubcap**	**Aerospace connector tool**	**Adapter for power charging station**
Company	Volkswagen	Russtech Engineering	KUHMUTE
Technology	SLA Clear Resin	SLS Nylon 12 Powder	SLS Nylon 12 Powder
Use Case	One-off	Low volume production	Custom manufacturing
Volume of Production	N/A	100 parts per week	N/A

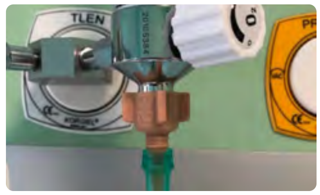
			
Part	**Lateral thruster for jet boat's pump**	**Air Duct for race cars**	**Motorcycle intake manifold**
Company	JetBoatPilot	GreenTeam University of Stuttgart	Help3D
Technology	SLS Nylon 12 Powder	SLS Nylon 12 Powder	SLA Rigid 10K Resin
Use Case	Aftermarket parts	One-off	One-off
Volume of Production	N/A	N/A	N/A

Electronics

			
Part	**Housing for a vehicle's control system**	**Housing for camera tripod**	**Casing for automotive telemetry display**
Company	IBL Hydronic	XSPECTER	BTI Gauges
Technology	SLS Nylon 11 Powder	SLS Nylon 12 Powder	SLS Nylon 12 Powder
Use Case	Low volume production	Low volume production	Aftermarket parts
Volume of Production	100-250 parts per batch	1500 parts per year	N/A

		
Part	**Armature for underwater device**	**Mounting ring for outdoor water meter**
Company	NOAA	NextMeters
Technology	SLA Standard Resin	SLS Nylon 11 Powder
Use Case	Low volume production	Custom manufacturing
Volume of Production	N/A	250+ parts

Healthcare


Part	**Covid test swab**	**Adapter for oxygen reducer**	**Housing for medical device**
Company	NAMIC	CAMT	Tension Square
Technology	SLA Surgical Guide Resin	SLA BioMed Amber Resin	SLS Nylon 12 Powder
Use Case	Stopgap during shortage	Stopgap during shortage	Bridge manufacturing
Volume of Production	210,000 parts per week	20+ parts	N/A



Part	**Occlusal splint and guard**	**Dental permanent restoration**	**Orthodontic braces**
Company	Atlanta Dental Spa	Argoat Prothèse Dentaire	Braces On Demand
Technology	SLA Dental LT Clear Resin	SLA Permanent Crown Resin	SLA Denture Teeth Resin
Use Case	Mass personalization	Mass personalization	Mass personalization
Volume of Production	N/A	N/A	N/A



Part	**Internal parts for protheses**	**Prothesis**	**Orthesis**
Company	PSYONIC	Partial Hand Solutions	aNImaKe
Technology	SLA Tough 1500 Resin	SLS Nylon 12 Powder	SLA Durable Resin
Use Case	Low volume production	Custom manufacturing	Custom manufacturing
Volume of Production	N/A	N/A	N/A

Case Studies

This section documents various internal tests run by customers of Fuse Series 3D printers in order to validate the performance of SLS 3D printed parts, including their durability and suitability for end-use applications.

Russtech Engineering 3D Prints End-Use Parts for Aerospace

BACKGROUND

Russtech Engineering is an award-winning supplier of aerospace and military products for a growing list of aircraft manufacturers and supplier partners. They design and manufacture precision electromechanical components, electrical wiring assemblies, lightweight connector backshells and accessories, as well as tooling for the aerospace and commercial industries. They received Parts Manufacturer Approval (PMA) from the Federal Aviation Administration (FAA) for many current production and legacy aircraft programs as well as many US government NSN items. Russtech Engineering's factory maintains a quality system that is ISO 9001:2015/AS9100 REV D registered.

The team supports about 50 distinct product categories with more than 2,000 product configurations, and over 500 customers spanning the globe. They have been using fused deposition modeling (FDM) and SLA 3D printing for prototyping and internal manufacturing aids. With the ambition to achieve on-demand manufacturing, they implemented SLS 3D printing in-house to produce end-use parts.

This case study describes how Russtech operates the Fuse 1 to manufacture one of their key products, the contact retention tool, as well as connector components that are installed in commercial aircraft.

PART DESCRIPTION

The RTCRT series, now superseded by the RTTL series, are aerospace-grade connector tools used at the end of the manufacturing process in a quality control step—on the assembly line or occasionally at the launchpad or aircraft hanger.

These tools are critical to aerospace electrical harnessing systems where there are sometimes hundreds of connectors that are included in cable assemblies throughout the aircraft. Each one of those connectors can have anywhere from three to 130 contacts. Those contacts should be engaged properly in the connector to maintain the electrical integrity and stability of the circuit. These tools validate the positioning and retention of those contacts during the assembly process. Some of the major wire harness manufacturers that support leading aerospace corporations, such as Airbus or Boeing, can attain up to 500,000 cycles on these tools.

The RTTL tool inserted into a connector. The probe in the front of the tool pushes on the pins or sockets of the connector to ensure they are properly seated.

Russtech has worked with multiple industry players for years and defined the specifications for the RTCRT/RTTL tools as an industry standard with a patented preset release mechanism.

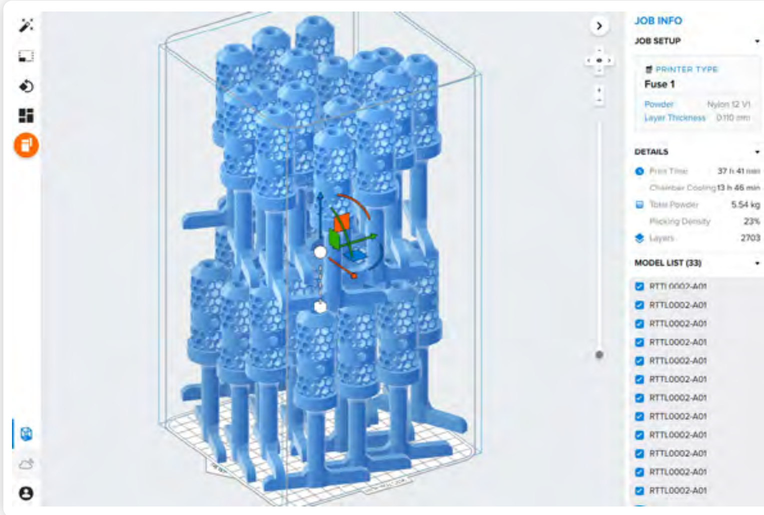
PART DESIGN AND 3D PRINTING

Russtech offers many discrete tool configurations to match various connector types and contact sizes. The RTCRT/RTTL tools are calibrated to a specific force range associated with the connector type. This level of customization demands great agility and flexibility in the manufacturing process. Therefore, for the new version of the contact retention tool, they chose to switch their production method from machining to 3D printing in-house with the Fuse 1.

The legacy contact retention tool (right) is an assembly of multiple parts. The body is machined Delrin, the wings are machined stainless steel, and the wing stop safety feature and handle are machined aluminum. The new tool (left) is almost entirely SLS 3D printed in Nylon 12. All versions have a metallic probe at the front.

Because they needed a strong, durable material, they selected Nylon 12 Powder, a material that is easy to print with and has low-warpage. It is also softer than stainless steel used on the legacy RTCRT wing-stops, which helps prevent the tool from causing any damage to the connector. To compensate for the lower impact strength when switching from stainless steel to nylon, they thickened some sections in the design.

They post-process the parts with glass bead media blasting and dye them black. As they can run three jobs per week with a Fuse 1 and pack 33 units per job, the team can produce 99 printed and post-processed tools per week.

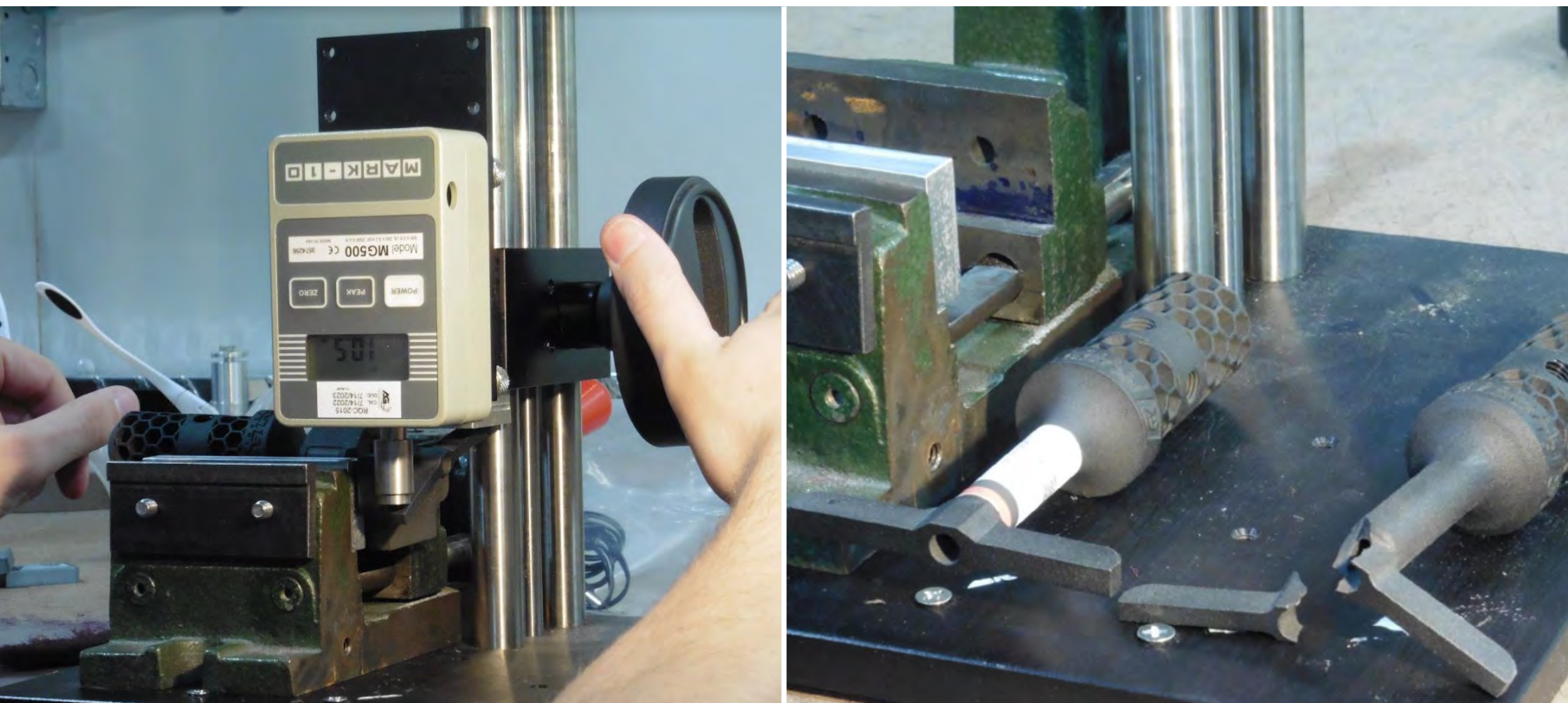


The CAD file of the tool body loaded into Formlabs' PreForm print preparation software. The Fuse 1 can fit 33 models into the build chamber with 38 hours printing time at a 23% packing density. This orientation ensures the surface of the wing stop is smooth and the main bore is straight to maintain the circularity.

IN-HOUSE TESTING TO MEET AEROSPACE REQUIREMENTS

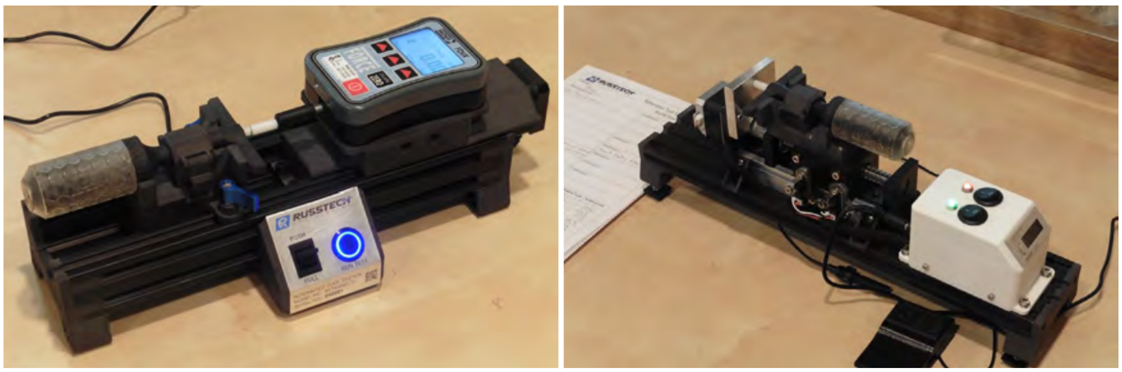
In accordance with Russtech's "design-to-quality" culture and the need for product validation, Russtech performs many mechanical tests in-house. They tested the impact strength of the 3D printed wing stop feature with a force gauge. The original 3D printed design failed under shearing at 15 pounds of force. After thickening the sections in every dimension, the 3D printed parts could withstand 35 pounds of force—the maximum of their tester—without failure.

Testing the impact strength on the wing stop of the tool 3D printed in Nylon 12. The original design version broke (right) while the new design (left) survived the test.



This demonstrates that the 3D printed part can resist falls, and live up to the stress of operation on the factory floor. They were able to design around the shortcomings of going from a metal tool to a plastic tool while taking advantage of the efficiency that additive manufacturing brings. To ensure the reliability and robustness of the tool, they put it through rigorous testing, developed in-house.

Release force is a critical property for the contact retention tool, it is calibrated to a specific release force range associated with the type of contact and connector. To verify that it is properly configured, Russtech built the Automated Tool Tester. It mounts an off-the-shelf force gauge that measures the release force of the mechanism. Then the tool is installed on a cycle tester.



Automated Tool Tester (left) and cycle tester (right). A prototype of the contact retention tool is inserted in the testers. The tool grip is 3D printed in Elastic Resin on the Form 3 printer and will be injection molded in black TPE for the commercialized version, while the core of the tool will remain 3D printed in Nylon 12 with the Fuse 1. The tests are run using a specifically designed Delrin test probe. This specific unit is calibrated to a 6 pound force with a tolerance of ± 0.5 pound.

The cycle tester stresses the tool: the test probe is pushed against a metal plate, actuating the tool in compression over and over until it reaches a failure mode. All models are tested to a minimum of 500,000 cycles for design validation. This is an extremely rigorous test that they could not previously perform.

Calibration of the legacy tool was performed with a simple hand-operated tester, mostly made of machined aluminum parts. However, these tests were highly operator-dependent, delivering inconsistent results. Consequently, they developed an Automated Tool Tester in-house, built from off-the-shelf components and parts printed on the Fuse 1 in order to ensure cost-efficiency.

Russtech Engineering is now starting to sell this tester, including all these new 3D printed components, to its customer base. This is a great example of moving from using 3D printed parts internally for simple prototyping and fixturing to incorporating 3D printed parts as a sub-components of an end-use product sold on the market.

The Automated Tool Tester is driven by a stepper motor, regulated by a custom control board to regulate the cycle speed. The body is made from extruded aluminum, while the feet and various fixtures and brackets are 3D printed in Nylon 12.

RESULTS

Reduce Manufacturing Time and Solve Repair Challenges

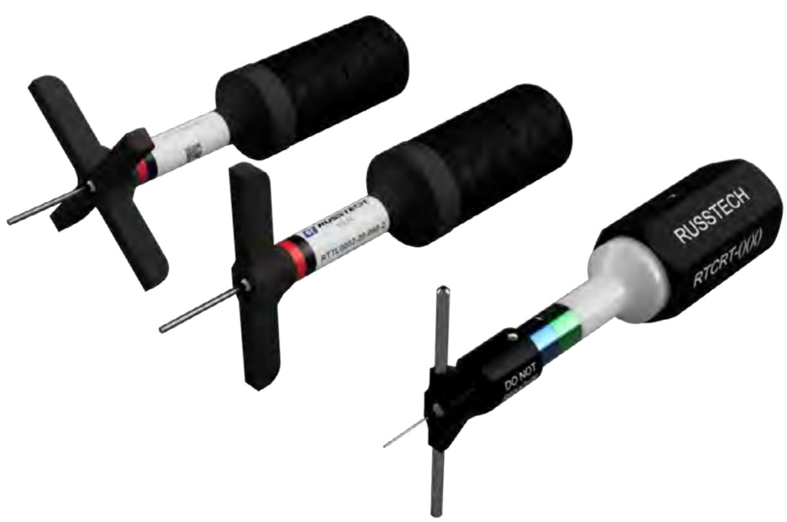
Because the legacy tool is an intricate assembly requiring multiple manufacturing processes and post-treatments, it required weeks and sometimes even months to be fabricated. By moving from outsourcing all these sub-components to 3D printing a single-piece body for the tool in-house, they managed to reduce the part count by 33% in the bill of materials (BOM). This new version of the tool is faster to build and calibrate, reducing labor costs, and overall cuts down lead times to days, getting closer to just-in-time manufacturing.

Repair activities are extremely time-consuming for the company. Even when charging for repair, they struggled to reach cost-efficiency against time for planning and inventory management. With in-house 3D printing, Russtech can reduce the cost per tool and transform this product into a consumable. Once it loses its calibrated values, the customers are instructed to dispose of the tool and order a new one. The company does not need to invest time in spare part management and stock planning anymore. They hold a digital inventory and can achieve on-demand manufacturing to decrease costs, reduce customers' downtime and ultimately increase customer satisfaction.

Historically, Russtech was producing 2,500 to 3,000 units of these tools per year. With a single Fuse 1 and a single build chamber, the team can produce 99 printed tools per week and easily surpass the former volume of production.

Increase Design Agility and Part Resilience

As the team eliminated repair management from the legacy RTCRT tools, they also increased its resilience. Thanks to 3D printing, Russtech has gained design agility and developed various body styles at no extra costs or time in order to meet distinct customer requirements. With CNC machining they would need weeks to plan new CAM programs, tooling, and post-processing.



The contact retention tools. From left to right: 3D printed tool with four wings, with two wings, and the legacy tool.

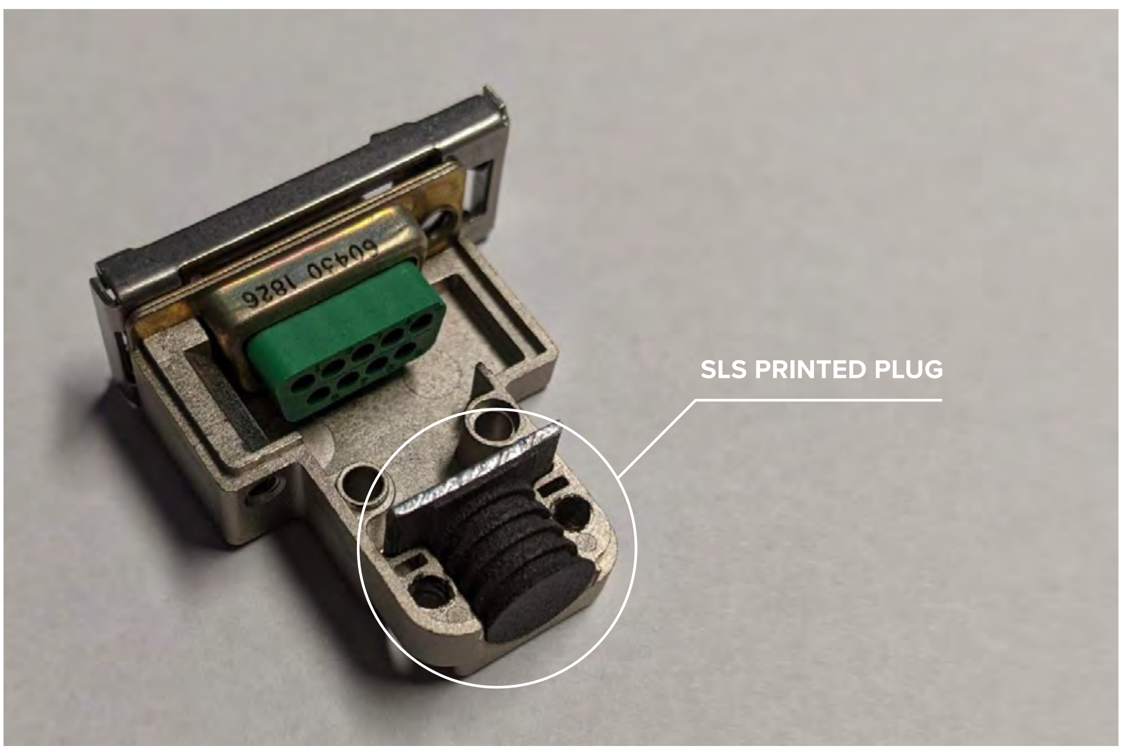
3D PRINTED CUSTOM IN-FLIGHT PARTS FOR COMMERCIAL AIRCRAFTS

Besides their core products, such as connector accessories and tools, Russtech Engineering also produces custom aircraft parts. With the Fuse 1, Russtech Engineering is 3D printing parts installed in commercial aircraft. One particular client's request was to manufacture a custom termination plug, which acts as a connector at the extremity of a wire harness. They employed one of their midline products; an injection molded EMI backshell and needed to add a customized plug that was secure, lightweight and met the aerospace requirements.

They needed only 25 made-to-order plugs. Such a small batch does not justify injection molding tooling costs, and machining them would have been cost prohibitive. They turned to SLS 3D printing with Nylon 12.

Nylon is not an aerospace compliant material. However, because it is a small part in such limited quantities, it was deemed safe and approved by Russtech's customer for being placed in an aircraft. A larger part present in higher quantities would need to be printed with a flame retardant material.

"We got the prompt from our customer, we responded with a digital lockup within a few days, and pricing within a week or two. And then we were able to build and manufacture these in about a month and a half, from the beginning of the discussion to delivery. So we were able to deliver flight qualified parts in a month and a half. In our industry, that's unheard of," says Ben Lebson, Senior Design Engineer at Russtech Engineering.



Connector made of an injection molded EMI backshell and a termination plug 3D printed in Nylon 12. EMI shielding tape was added to provide an electrical, EMI shield.

Next Meters Simulated 15 Years of Extreme Weather Exposure on SLS Printed Parts

BACKGROUND

Next Meters is a manufacturer of connected water metering tools with a mission to educate and reward individuals who conserve water. They create solid-state flow meters that measure water usage by residential, commercial, or municipal customers. The team has been using multiple Formlabs SLA printers to speed up the product development process with rapid prototyping. Then they implemented SLS printing in-house with the Fuse 1 for the custom manufacturing of end-use parts. Their challenge is creating equipment that can affix to the wide variety of utility applications currently in use.

As the meter type differs with each city, Next Meters needs to customize their IoT devices to fit with each category of metering equipment. Most models are widely used, which makes it cost-effective to injection molding these components. For about 20% of the market, however, the production volumes are too low to justify injection molding tooling costs. They needed a solution to manufacture dozens of small batches of final parts that will be left years in the field.

In order to validate the performance and durability of Fuse 1 printed parts, they ran a series of internal tests. This case study describes how they applied accelerated aging to nylon printed parts.

Next Meters custom water meters installed in a building's pits.

PART DESIGN AND 3D PRINTING

The part considered in this report is a mounting ring that attaches Next Meters' IoT device to any existing water meter. The design was modeled after their injection molded parts.

They could simplify the geometry by eliminating molding features such as draft angle, ejector pin locators, gating locations and uniform thickness. The self-supporting nature of the SLS print bed allows for building intricate parts with internal features, without supports. This ensures the high quality surface finish required to preserve the water flow in ultrasonic water devices.

The mounting ring was printed with Nylon 11 Powder on the Fuse 1 printer. The team needed about an hour for post-processing following Formlabs 3D printing instructions and sand blasting. They chose Nylon 11 Powder as they needed a strong and flexible material for the locking tab to snap into place. To ensure the durability of the part, they implemented stress testing in-house to mimic conditions in the field, using environmental chambers.

CAD model of mounting rings loaded in the PreForm print preparation software. The Fuse 1 can fit nearly 30 rings per build, with about 30 hours of printing time per job.

ENVIRONMENTAL TESTING

The team used the Thermotron SM environmental chamber, controlling humidity and temperature. They placed samples of the mounting ring installed on the meter body inside the chamber. A group of samples was submerged throughout testing in a tub of water, while another group was in the open air. There were no significant differences between the two groups after testing.

They ran the following seven hour test cycles:

- The temperature at 70°C held for three hours.
- The temperature ramped down to 0°C in 30 minutes and held for three hours.
- The temperature ramped up again to 70°C in 30 minutes.

The mounting ring 3D printed in Nylon 11 with Fuse 1 (top left), fitted onto a unique water meter (bottom left), and assembled with the water meter register in clear casing (right).

Thermotron SM environmental chamber (left) and samples installed inside (right).

RESULTS

The team ran the cycles described above continuously for three months. This equates to an estimated 15 years of extreme weather exposure. This particular device is installed in a pit and will not be subject to direct rain and sunlight. For other parts, Next Meters also conducted testing with a rain chamber and a UV chamber. The team inspected surface quality, water content, and visual marks of wear on the samples. The printed parts did not show any signs of failure or significant deterioration, validating their durability and suitability for this end-use application.

Picture of the water meter after three months testing.

Next Meters has already installed several hundred products that include components 3D printed on the Fuse 1 in the field. Without the Fuse 1, they would have to injection mold the parts, which would require expensive tooling and come with three to four months of lead time. Factoring in the cost per part for both methods and the cost of tooling versus the cost of printing on the Fuse 1, they save about $3,000 to $4,000 per batch. With a product that requires many types of adapters in low volumes, these savings quickly become significant.

“There are dozens of meter models out there with quantities so low we’d never recover tooling costs. So, for those specific meters, we’re printing the parts on the Fuse 1 as needed. We can now deliver equipment for both the commonly found meters as well as the other 20%, and we can do it much faster and cheaper with the SLS printer,” says Next Meters COO David Clyde.

Next Meters’ internal tests have very aggressive test cycles, well beyond what their product would experience in the field. It is a great example of rigorous testing run internally using environmental chambers. The next section describes how a small startup with limited budget employs Fuse 1 parts for end-use applications, and validated material performance with limited equipment.

The KUHMUTE multi-modal charging hub.

Startup KUHMUTE Stress Tested Fuse 1 Parts In-House With Minimum Equipment

BACKGROUND

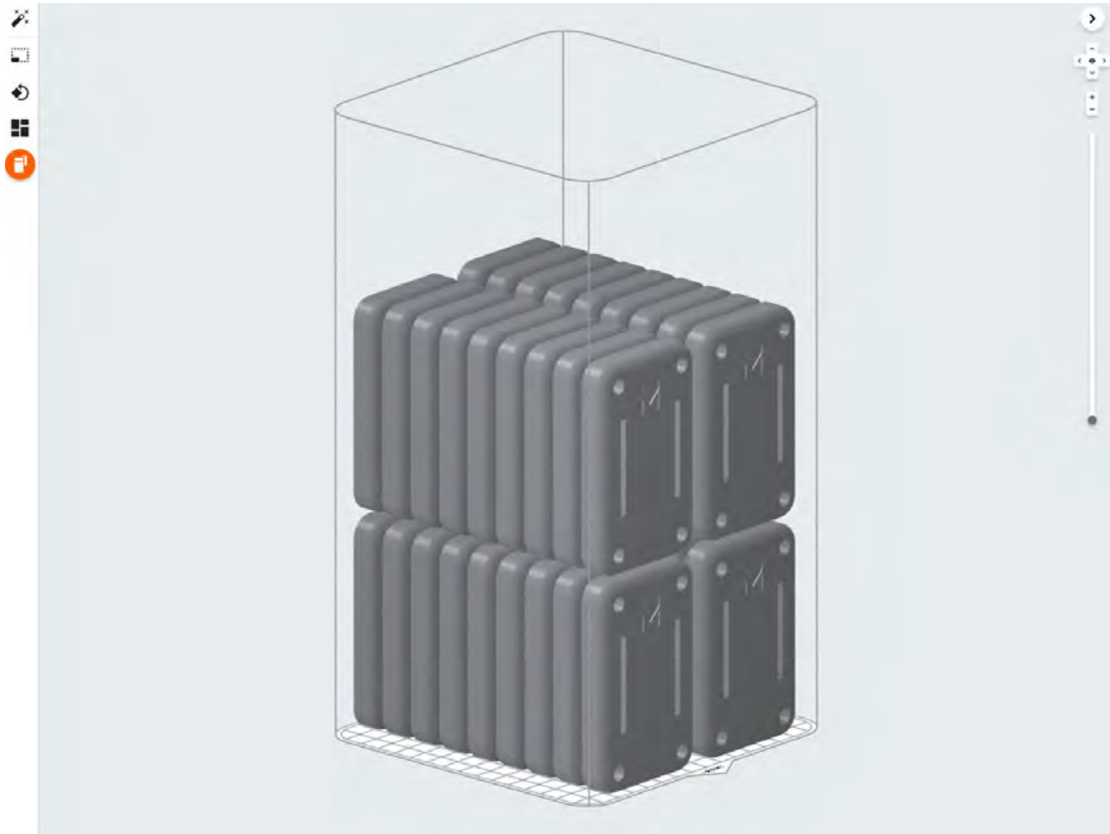
KUHMUTE designs and manufactures multi-modal charging networks for micromobility to help cities and mobility service providers bolster their transportation infrastructure. KUHMUTE offers a product that is best described as a combination of an electric car charger and a gated parking system. This flexible charging infrastructure enables e-bikes, e-scooters, e-skateboards, and autonomous delivery robots to recharge between trips.

The team has been using FDM 3D printers for rapid prototyping adapters to integrate new vehicles to their network. But to manufacture these end-use custom adapters on-demand, they turned to SLS 3D printing with the Fuse 1.

Born out of a thesis project, KUHMUTE is growing the startup tech space in Flint, Michigan and is committed to manufacturing locally in a sustainable fashion. With limited equipment, they achieved stress testing internally to validate the suitability of Fuse 1 printed parts for end-use.

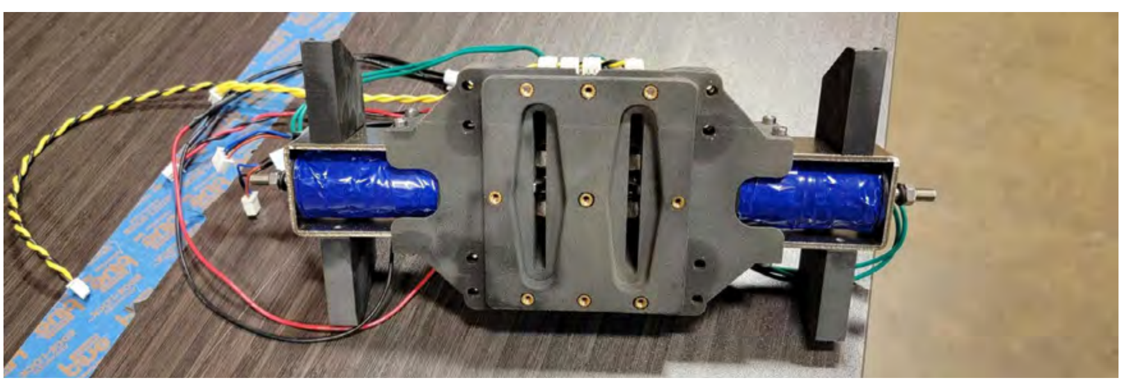
PART DESIGN AND 3D PRINTING

The company builds adapters made specifically for each vehicle type or model. They 3D print a variety of items that go inside the charging hub and around it, such as electrical brackets and housings for the locking components. To carry out stress testing, this case study considers the port of the adapter, on which a vehicle can plug into for both charging and locking.

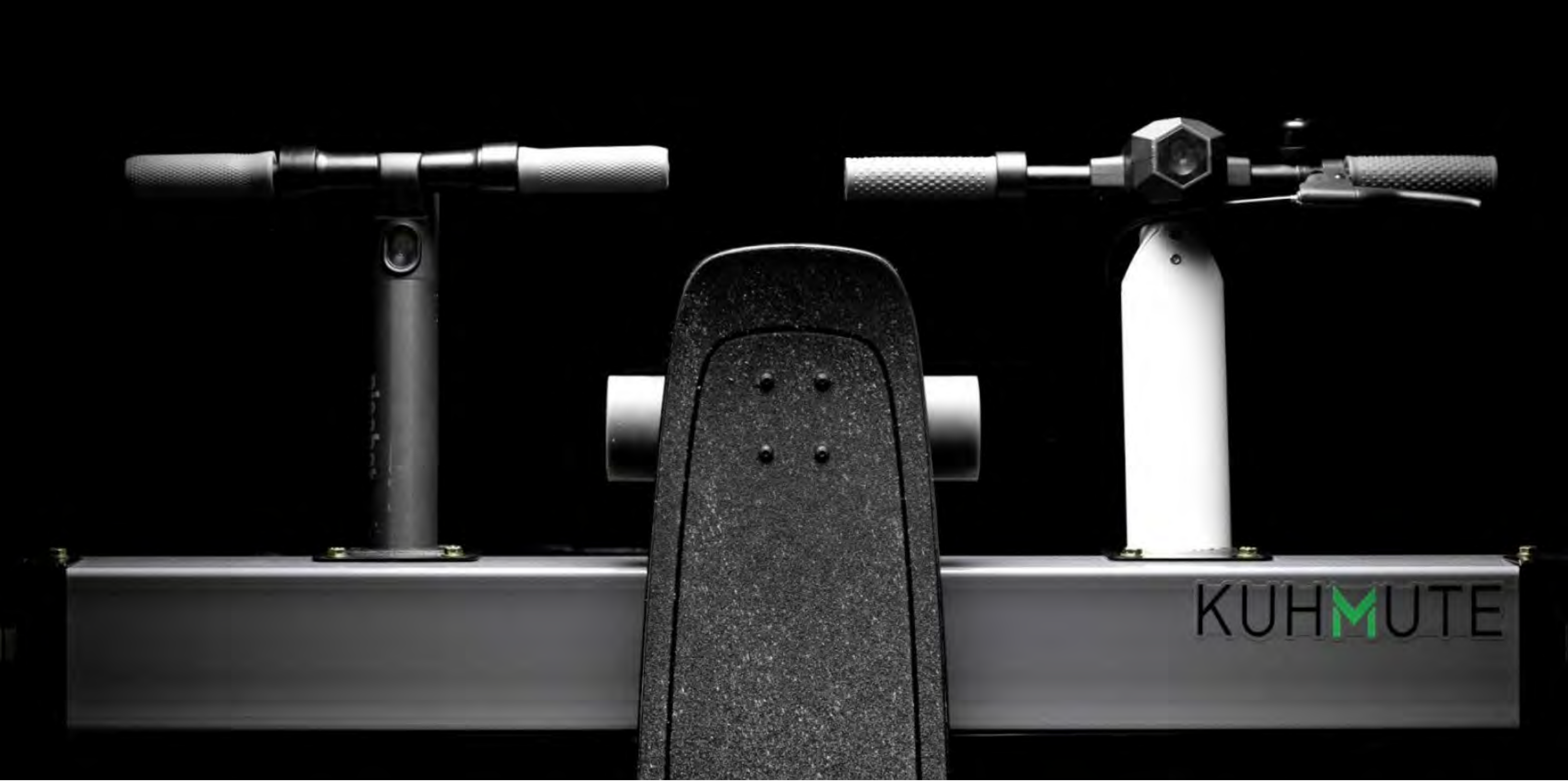


The CAD file of the port loaded into PreForm print preparation software. The model was designed in Fusion 360. 36 units fit into the build chamber of the Fuse 1 with 36 hours printing time. The part orientation is chosen to optimize the packing density.

KUHMUTE 3D prints parts in Nylon 12 Powder with the SLS Fuse 1 printer, following Formlabs' 3D printing instructions. They selected the Nylon 12 Powder as they needed strong and durable components with high environmental stability. All units undergo extensive beta testing in the field. They run thousands of test cycles in standard operation then move to destructive and weathering testing, comparing FDM and SLS technologies.



The port of the adapter 3D printed with the Fuse 1 in Nylon 12 Powder.



IN-HOUSE STRESS TESTING

Destructive Testing

In destructive testing, the team installs the vehicle on the charging hub and stresses it to failure, applying forces in every direction. This gives an understanding of the strength and stability in every dimension. They visually inspect the part to determine the breaking points and modes of failure in order to make adjustments in the design, print orientation, printing technology, or the material selection. They also ship the beta parts over thousands of miles routes to understand how components can handle the abuse of shipping and which design features need to be corrected.

Weathering Testing

In beta testing, the unit is left in the field for several months for natural weathering. They observe how the part bears temperature fluctuations (ranging from -15°C to 38°C), UV, rain, and hail exposure by inspecting warpage, shrinkage, and failure marks. To assess waterproofing, they water jet the part under high pressure and examine any presence of leak, moisture and water absorption.

RESULTS

Material and Design Iterations

The material selection for the port was made after the results of the destructive tests. PETG and Nylon samples 3D printed with FDM broke during long distance shipping while Fuse 1 Nylon 12 Powder parts survived without any damage. Once the team swapped to this material for stress testing in every dimension, they noticed a significant increase in strength and durability on each axis.

Water absorption and heat resistance were other restraining factors for selecting PETG and nylon samples printed with FDM. As the temperature inside the hub goes up to 90°C when operating, the FDM components deform and melt under heat. Because Nylon 12 Powder printed on the Fuse 1 has a HDT of 171°C (at 0.45 MPa), switching to this material increased the thermal resistance drastically and ensured the item would protect the internal electronics and survive weathering.

CONCLUSIONS

“We're achieving high-quality, aesthetically pleasing parts. The only post-processing we do is just removing the material. We are dyeing some parts just black so that way they fit in better with the aesthetic that we have. We really like how it's just a one-step process essentially for post-processing. It's just removing the material. So it's fairly simple for what we need and that's really what we're achieving is just production-ready parts as quickly as possible on an on-demand basis,” said KUHMUTE co-founder and CEO Peter Deppe.

Thanks to custom-made components with SLS printing, KUHMUTE can build 20 to 25 new hubs per month, each one including over 50 3D printed parts. They currently support 14 different vehicles and have installed hundreds of charging hubs in various cities in the United States. By moving to 3D printing end-use parts in-house with the Fuse 1, they were able to create parts with complex geometries that other technologies such as injection molding could not achieve, reduce production time from weeks to days, and sustain local manufacturing.

Get Started With 3D Printing End-Use Parts

Historically, 3D printing was not considered a solution for end-use plastic parts and was relegated to the realm of prototyping and design. But as 3D printing materials and technologies continue to advance, the optical and mechanical properties that can be achieved by 3D printed parts are now often able to surpass traditional manufacturing standards.

SLA 3D printing is already widely adopted by the dental and medical industry to 3D print biocompatible custom medical devices, and by a growing number of manufacturers for producing consumer products. Thanks to recent improvements to the SLS 3D printing process and powders, manufacturers are also adding this technology to their wheelhouse to 3D print strong, long-lasting functional parts for end-use consumer products as well as parts for industrial applications in aerospace, electronics, or transportation.

Freed from the tooling constraints of traditional methods, additive manufacturing is a powerful solution to produce on-demand parts with minimal lead time. In-house 3D printing enables businesses to take control of their manufacturing, reducing production time, costs, and risks.

Request a free sample part to see Formlabs 3D printed materials firsthand and contact our 3D printing specialist to find the right solution for your application.