Verhelst Associates

THOUGHTSTARTER SERIES

By Ray Verhelst

The Bicycle Industry: A Conundrum For Domestic Manufacturing

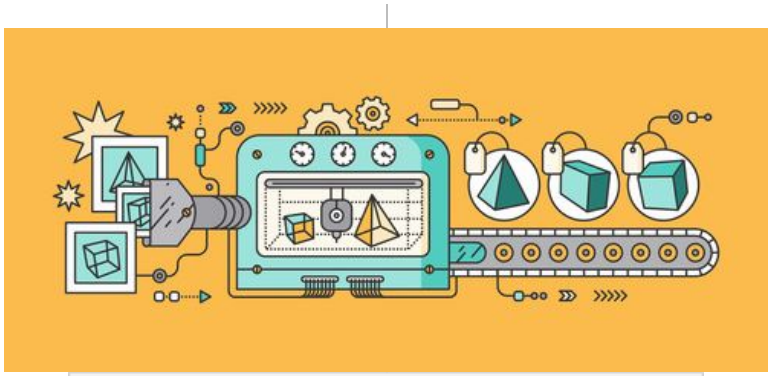
There's a new resurgence of creativity, engineering, and manufacturing that is decidedly aimed at an 'American Made' platform. Much of the motivation behind this is "Customer-Driven Manufacturing" which comes with expectations of high product quality, order accuracy, flawless fulfillment, and short-notice production runs.

This disruptive mandate requires a new thought process from the manufacturing floor to top-level management. This report looks at the feasibility of bringing back profitable production to the U.S. Bicycle industry that is flexible, quick to market, and offers real expectations for the current marketplace and potential export opportunities. It's no secret that much of it relies on technology.

Three Dimensional Manufacturing

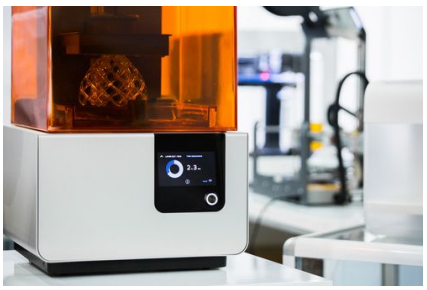
The idea of taking a product design from a CAD-based, engineering computer screen and sending it directly to a three-dimensional printer, thereby avoiding so many of the costly (both in time and money) manufacturing steps, has been

a pipe dream for many designers and developers.



From design through software to 3D printing: A desktop solution

Imagine the ability to produce highly technical pieces and parts for automobiles, aircraft, medical devices, and now bicycles to where concepts and prototypes with amazing complexities can come to life in days rather than months. Add in color and texture options as well to make it even more compelling.



What started as an engineering exercise in the mid-1980's with desktop printing devices that could print thousands of micro-sized layers of hot plastic to produce a fully scaled shape from a computerized drafting program in a matter of a few hours, opened doors for entrepreneurial "Makers" for everything from crafts to medical devices. Figurines, small cell phone holders, working nuts and bolts, and other experiments like prosthetics were produced without the aid of intermediate injection molds, or milling stations. Most saw this as the next step in prototyping where you could touch, feel, and evaluate a part before committing to expensive mold making or production-level machining.

Known as an additive printing model backed by U.S. patents, the software interface would take the solid three-dimensional shape envisioned inside of a computer drafting program and slice it up into layers no thicker than a hair and send the patterns to a printer head that moved like a drawing plotter that extruded hot plastic out in succession. As the layers fused together from the heat, the part would take shape from the bottom up.

I emphasize the U.S. creativity, engineering, and patent development side because 3D printing is like the emergence of the lithium battery story, where a contingent of U.S.scientists, chemists, and academics developed groundbreaking Li rechargeable battery technology only to have the government determine that the product would be too costly for public use. As a result, by 1991, Sony, supported by the Japanese government, had built the first commercial lithium battery into a national industry. The difference is that we have hopefully learned from that mistake and are leading the charge to fundamentally change manufacturing processes through these new methods.

Politics: No getting around it

An important motivation for this article has to do with the current state-of-mind in both the U.S. and the EU to utilize tariff penalties as a method to force equalization against Asian imports, in particular, China. For the bicycle industry, these

penalties are creating a measurable ripple effect that will trickle down to the consumer.

The most recent U.S. tariff penalties started with complete electric assist bicycles back in August and have extended their reach into the complete bicycle component market through a second round of tariffs that immediately adds a 10% bump. This interim stage will increase further, climbing to 25% by January 1, 2019. These percentages are in addition to the existing import tariffs already in place in the U.S. which range from 3.4% for parts to 11% for a complete bicycle. The 25% tariff for complete electric bikes and the combined 36% for traditional bicycles starting in 2019 provided additional incentive for this article's discussion.

Technology Improvements

As with the age of the desktop computer, the evolution of three-dimensional printing has come a long way in just a few short years. Acting on two fronts, the mechanical extrusion devices

An assortment of items printed with the Formtool Fuse 1 technology

now include lasers that sinter the materials through bonding agents on each layer and a selection of heat and UV curing to finish the parts. The accuracy has resulted in dramatically higher levels of details and finishes, as well as print speeds ten to twenty times faster.

At the same time, the chemical engineers have been working on the material science to allow part printing in more durable nylons, temperature resistant plastics, and now metals. Steel, aluminum, and even hybrid titanium blends are being perfected. Like the Moore's Law of Personal Computing, industry experts project that advancements in 3D print technology will be fully competitive against traditional part manufacturing within the next three years. GE's recent announcement that they had reached a milestone of 3D printing exemplifies this point with the company producing more than 30,000 metal jet engine fuel nozzles in its Alabama-based plant.

Rather than get into the soup of technical details, we took a tact on how feasible it is to produce finished, ***performance-level*** bicycle components from these new technologies and asked the question could the production be competitive in both price and quality when compared against large Asian manufacturing facilities?

Could a semi-automated operation with a number of different flexible print and finishing technologies, supported by robotic intermediaries and a smaller staff of skilled

production engineers turn out ***medium to high-performance*** bicycle products in enough volume to generate a profit? If so, the next question is whether there would be both a domestic market as well as an export market for these products?

The Hard Facts

To be truthful, the entire bicycle industry for North America is but a drop in the bucket for global demand. By comparison to sales volumes in India, China, and even the EU, we offer what would be considered a niche market if based solely on the numbers. But our Asian suppliers see the U.S. market as a prestigious goal and therefore are willing to negotiate and engage in business opportunities.

In general, a significant portion of financial lenders don't see the same optimism that government officials do when it comes to retrieving some of the lost industry manufacturing from the 1990's or earlier. For the bicycle market, there's not enough demonstrated demand to underwrite dedicated factories, finance specific machinery, or develop craft training for an undetermined workforce. Part of their escape clause is to evaluate what the facility and equipment could alternatively be used for if this endeavor fails. And more importantly, at what return value?

Banks and venture capital funds look for significantly larger multiples on earnings, as well as scalability. It's not uncommon for the prerequisite to be 8 to 16x earnings as a 60-month projection. This is but one of the significant barriers to entry for non-government funding of manufacturing in the U.S.

In a discussion with one banking expert, the question arose of "how long will these tariffs be in place?" While the EU's position is more about protecting an existing manufacturing infrastructure, the U.S. bicycle industry doesn't have that. Would there be wholesale changes with a new administration? He indicated these answers would be factors in any long-term financing package.

On Capitol Hill, we questioned congressional sources to determine when the last time there was a wholesale change in the reduction or outright elimination of import tariffs? The answer was the record shows that only if there is a bilateral or multilateral trade agreement between countries, or if a state representative (House or Senate), or a group of officials petition the USTR to have particular tariffs reduced or eliminated on goods that affect manufacturing and jobs in their respective states. This happens once a year and typically requires the item source to be from "Favored Nation" status partners. At this time, China is not one of them.

When compared against the dedicated manufacturing centers in China and Taiwan, it would be unreasonable to assume that a U.S.-based operation could be competitive globally against a complete, well-entrenched industry. As an example, we are talking about the Giant Bicycle factory in Taichung that takes up more than 67,000 square meters (721,182 square feet). Collectively, this one brand has nine manufacturing facilities, located in multiple countries and produces more than 6.3 million

bikes annually. But this “brand” actually is an OEM parts producer for a number of the top brands out there besides their own, including Trek and Specialized.

Inside the Giant Bicycle factory in Taiwan

By comparison, the global manufacturing of bicycles annually is projected to be more than 80 million units.

These facilities are dedicated in design and besides the structures, the purpose-built machinery used for extruding, forming, welding, finishing, and assembly are often extremely unique and cannot be quickly transitioned over to produce something else. It requires special jigs, molds, dies, and programming to complete many of the parts. The changeover also requires months of design and sequence engineering. Prototype development, testing, and manufacturing feasibility all become critical factors when looking at a final product.

Let’s also look at the workforce. Thousands of employees work and live on or near the manufacturing compound. They are assigned to specific functions on critical assembly lines with daily quotas. Cross training is limited and on-the-fly decisions are almost non-existent.

We should also tackle the elephant in the room, which is the cost of labor. While it is often used as the key differentiator when compared to domestic production, what most fail to realize is that over the last 6 years, there has been five “cost of living” wage increases in China that have been significant in the formation of the country’s new middle class. Domestic consumption has grown substantially and the cost of export transportation has increased dramatically due to the lack of available outbound ocean-going container space. All of this has created a much closer parity for pricing and that was before the tariff penalties where put in place. The reality is those pricing variations are less about the lower cost of labor and more about the economies of scale.

A Different Business Model

Given the potential size of the U.S. market and the possibility of exporting well-made, non-tariff penalized items to the EU, we created some reasonable parameters. We proposed no larger than a 20,000 square foot manufacturing facility, which would be based in a common industrial structure rather than a purpose-built factory. We created a budget of between $500,000.00 and $750,000.00 for the equipment, which would be financed and/or leased, and additional figures to support a manufacturing team of 15 to 20 well-skilled individuals.

The scenario was proposed during a number of interviews with representatives from four of the top 3D printing manufacturing companies, as well as a group of material scientists and finishing specialists. We also spoke to engineering entrepreneurs who were in the midst of launching actual products for the bicycle industry that were based on 3D printing technology.

In full disclosure, we also integrated state business incentives into the plan that are geared towards localized support for technology startups ranging from equipment tax abatements to employee job training initiatives. Many states offer these types of incentives so it was a reasonable assumption.

In doing the research, we dove head first into the current world of 3D printing and the different technology platforms. While we will avoid deciphering the heavy details of the different print methods in this article, it is fair to say that all of today's print options go well beyond the hobbyist platform and offer really high-quality production capabilities. We also learned that the industry leaders we contacted are not Craft Maker style startups. We're talking about organizations that are well funded to the tune of hundreds of millions of dollars, with projected values in the billions. This includes brands like HP and Formlabs, and engineering teams launching patented technologies from the likes of MIT labs.

Arevo Inc.

In our first discussion, we spoke to Mr. Hemant Bheda, Co-Founder of Arevo Inc., a Silicon Valley-based "Additive Manufacturing" technology firm. Mr. Bheda has developed a unique large format (48" x 48" x 40") three-dimensional print area on his device that is supported by the latest 5-axis ABB robotic arm to move the print head around. Our motivation to start the conversation with Arevo is that they used their design and fabrication technology, with more than forty different patents, to produce

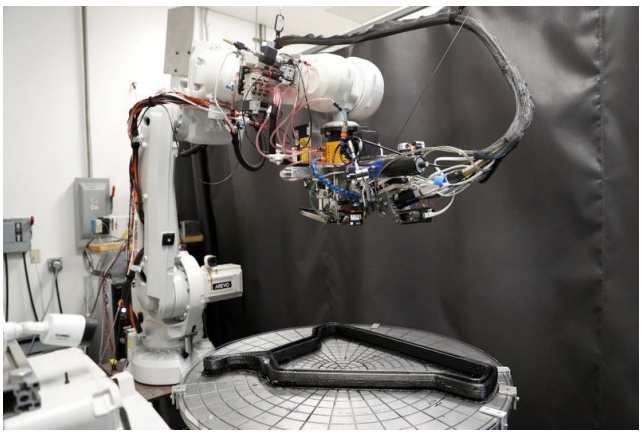
Arevo 3D printed Carbon Fiber bicycle frame

a series of carbon fiber bicycle frames as a proof of concept.

They reached out to StudioWest to help design the frames for a number of different platforms, including an e-Bike. One of the key components of the Arevo system is that they also developed a software-based, real-time engineering design tool that can evaluate the load and stress factors to be applied to a given product. The system can take into account the pressures generated by weight and motion. It can calculate visually on-screen, torsional stress and rigidity, as well as joint stress points of a given part.

Matching this CAD-based simulation with their ability to use the five-axis print head allowed Arevo to develop a layering method that inserts strands of carbon fiber in the proper direction to address the needs of the design as it builds the finished product. Unlike traditional matte layers of the substrate, this method makes the finished product stronger, lighter in weight and perform better under use loads.

While the engineering prowess is powerful, the real benefit is that the carbon frame designs with all of the virtual structural analysis, internal cable chase routing, and unique complex form shapes, went from concept to a finished product in eighteen days! This is opposed to prototype building, the development of custom molds, forming jigs and multi-part assembly processes, which cost from the thousands to tens of thousands of dollars.



When the StudioWest designers were able to actually test ride the product that they envisioned weeks before, they not only found it to be well balanced as a bicycle but a true work of art. What typically takes an average of 18 months, with the supporting expensive tooling was complete in less than a month. There we no additional forming jigs, molds, or assembly supports. Labor beyond the computer operator consisted of one individual to set the machine up, maintain the material flow and monitor for issues.

Adding to the structural capabilities was the fact that Arevo had managed to develop a print layering process that the level of density within the finished print was under .1% in terms of voids. This means the layered print was as close to a solid mass as possible.

Mr. Bheda has a software background that includes a lengthy stint at Intel, and his new CEO is actually a former top executive from Google. His work with Autodesk and other engineering platforms has allowed the company to create parametric design tools that will allow items to shrink or grow as needed and be able to go through higher structural testing extremes before even becoming a prototype. Arevo's optimization system has already proven to deliver printed goods using their additive process at more than 10x the traditional speed.

Arevo's additive print system uses a hybrid of formation processes, including lasers that activate the bonding materials between layers. Their material science team has also been working diligently on the development of the materials chemistry. We asked about the repetitive accuracy the robotic arms, to which Mr. Bheda responded, "The movement of the arms and print head can be controlled to within millimeters and the remote monitoring with sensors and video cameras allow for instant notification and adjustments in real-time."

Both the traditional road bike frame and the recent eBike model that has been developed to integrate a new German-based electric drive system with a built-in 3-speed transmission were on display during Eurobike this summer. Mr. Bheda has confirmed that the final carbon fiber frame cost is projected into the $300.00 range,

which is very competitive against some major Taiwan counterparts.

The eBike has actually found a customer, and while the company is not focusing exclusively on the bicycle market, they have accepted a purchase order for a significant number of eBikes that will come out of an eight print station manufacturing center starting in the fourth quarter of 2018.

It should be noted, that currently, part of the finishing process involves traditional sanding machines and hand processing, before the frames receive their finish coats and graphics.

The plan calls for Arevo to establish the first of its numerous production centers with remote-controlled robotic manufacturing systems each capable of 24/7 operations. Our proposed facility could become one of the manufacturing centers.

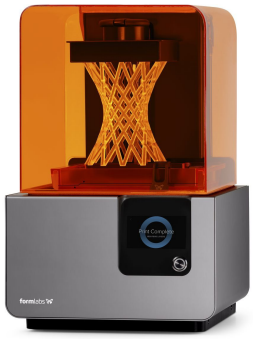
Formlabs, Inc.

Our next interview was with Mr. Andrew Edman, an Applications Engineer at Formlabs, which is a Boston-based technology company with more than 500 employees that has expanded its presence to facilities around the globe.

As one of the earliest desktop printer manufacturers, the company took a different route by developing a laser-driven, stereolithography printer back in 2011. The technology was born out of the MIT Media Labs by three students.

Fast forward to today, and Formlabs has continued to maintain their desktop relationship with the Form 2 but has managed through tremendous funding sources to develop the commercial Fuse 1, which is a selective laser sintering printer that can produce volumes of nested parts in a single run. The company has also reached the $1 billion dollar market value.

Their desktop model, Form 2, uses a liquid-based material that grows layer-by-layer from the top down as the platform rises out of the resin. Their uniqueness was based on the compact size, ease of use, and quality of the finished part for the price.



For our business case study, we concentrated on the new Fuse 1 system (officially called a powder bed fusion process), which is based on a Nylon 12 powder substrate (each grain is about 50 microns each) that is spread in micro-fine layers through automation within a build area that is 6.5” x 6.5” x 12.5”. The build platform actually moves downward within the chamber layer-by-layer and the laser sintering activates the only the materials within the specific pattern needed to create each part, leaving the rest of the powder to act as a support. This is extremely important as it allows for volume nesting of parts into the print production.

In one example, the Fuse 1 prints fifteen pairs of high-quality mountain bike pedals from durable nylon. The design also can include the necessary threaded receivers for machined steel pointed inserts for better shoe traction, as well as the metal bearing shaft insert to mount the pedal to the crank arm.

Besides the printer, there is a recovery station that allows you to separate the finished parts from the surrounding loose powder and brush them off. The goal of this station is to capture as much of the unused nylon.

The nylon materials not activated by the laser can actually be recycled and used again when blended with a percentage of new material, keeping the overall costs down.

The third station is the powder mixing station that takes the sifted unused nylon powder and blends it into a new canister ready to be loaded into the printer for the next run.

In our business scenario, we talked about having multiple printers feeding a single part recover station. At $10,000.00 per printer, it is reasonable to see three to four printers as part of the package. Raw material costs are still being finalized but product tests indicate the nylon products meet or exceed a typical injection molded part for structural integrity.

With the complete canister print time in the six to seven-hour timeframe and with no human intervention, there is a reason to add more printers. But it is important that these timelines allow for a second overnight run, which can be monitored remotely, increasing the equipment's productivity without increasing the labor.

You may ask why would you want to compete against a high volume injection molded operation? The answer is more about the personalization of these parts. A simple modification to the drawing file to include the shop logo inset into the part is something almost impossible to do in a high volume production run. Another challenge is making parts that adapt to specific product models. Producing countless molds for variations is not practical, considering you're not sure how many of each will be requested. Color and texture are other options too.

The idea of inventory controls over a larger selection of size and/or finish specifications, and Just-In-Time manufacturing is critical when factoring a business model. There are fixed upfront costs for tooling and injection molds, and change over in machining which is often impractical for short run production.

It is also important to note that product design engineering takes a completely different approach when producing 3D interconnecting parts. Items with movable joints can actually be printed as a single entity with the hinged items already linked. Goods come out of the printer canister already articulating without the need for additional assembly. The part design path doesn't need to take into account mold releases or excess material due to an extrusion process. Parts can incorporate complex honeycomb internal structural support that can increase strength while reducing the overall part weight.

The challenge with this print platform is the actual finish. If a stippled, micro-layered effect is acceptable then the parts are ready to go. But if you want a polished or satin finish with a smoother surface, then you need to have a second processing line to complete those steps. We'll get into that later.

HP Systems

Everyone knows that HP has been synonymous with printing technologies since 1984. But what few know is that their micro spray inkjet technology has been adopted to their new line of Fusion Jet 3D printing solutions. The HP system

A production center with a fleet of HP Fusion Jet 3D printers and cleaning stations

has advanced the powder-based fusion process but the particles are smaller and the layer spreading device operates in both directions. Instead of using a laser to introduce heat, the HP system sprays 350 million fusing agent droplets through 30,000 nozzles which activate the binding process with the internal heat source. This activation process also operates in a bidirectional mode. The sheer volume cuts the print production time dramatically. In addition to speed, HP has developed a finer powder nylon substrate that improves the structural integrity and delivers a smoother finish. Each layer is approximately .003 inches in thickness.

According to HP, the build volume area inside of an HP Fusion Jet 4200 printer is 15” x 11.2” x 15” and the print canister can be removed to facilitate the cooling process while another canister can be loaded to keep the production process moving.

Like Formlabs’ print solution, the HP also has a material collection station where the parts are separated from the excess powdered substrate. The printing process is fully automated, but the cleaning and powder collection is semi-manual. I say semi because the station is well equipped with vacuum systems under a laminar hood.

The HP system can also produce parts in multiple colors at once. The difference is that the HP Fusion system will run you around $100,000 to $200,000 for a single printer and $25,000 for the material collection station.

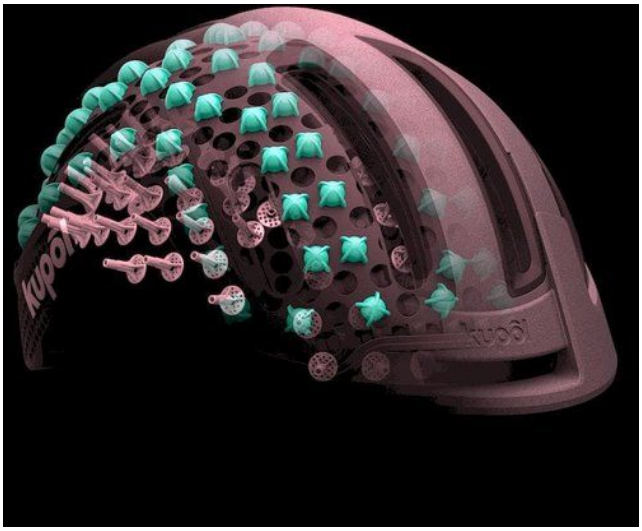
This seems expensive, especially if you plan to install more than one printer, but when compared to a computer numerical controlled milling station used for metal mold production and precision metal parts, you are talking about $150,000 plus the tooling which will run $2000 to $3000 per month in sharpening and replacements. Ironically, they typically work on one component at a time.

HP Metal Jet has just been released and is prepared to tackle commercial part production volumes with calculated machine break-even figures in the 50,000 part quantity.

The Kupol Bicycle Helmet

Gabriel Boutin, the founder of Syncro Design, an industrial design firm with expertise in 3D Additive manufacturing out of Canada, has

developed a new bicycle helmet line under the project name of Kupol. The entire design is based on the capabilities of the HP Fusion Jet system. According to Gabriel, the concept of the helmet and the complexity of the parts and structure could not be replicated through standard injection mold processes. Using an advanced (and patented) lattice support structure, the helmet allows better airflow to keep the rider cooler. Because the printer can produce both rigid and flexible nylon parts, Kupol integrates both to provide as many as one hundred touch points with the head and can be custom fitted more easily than traditional polystyrene pads.



The Kupol project is planning to take parts from the HP printer, run them through a finishing phase and assemble them for customer delivery. The design also allows for select color accent components to be incorporated into the finished products.

The helmet project launched itself on Kickstarter and to date has raised more than 30% of its target with a few weeks to go.

Traditional cycling helmet manufacturing for this type of product would require a set of molds and tooling that would cost in excess of $200,000 to cover the sizes. On top of that, the finishing and graphics add a tremendous commitment, before you can even produce a single consumer product.

Markforged

To round out our 3D print hardware profiles, we spoke to Mr. Andrew Geofroy, the VP of Application Engineering for Markforged, which is another Boston-based company that started in 2013.

Founded by Greg Mark, the company's philosophy is to look at 3D printing for manufacturing as a holistic problem. They strive to build an end-to-end print solution that is competitive with traditional manufacturing of prototypes, tools, and fixtures, as well as production quality end-use parts.

The company's initial foray into 3D printing was a desktop unit called the Onyx One. Similar to the more crafty desktop printers in size and format, the Onyx One has a more industrial feel and the ability to integrate reinforced layers of strand-based substrates like fiberglass and carbon fiber into finished parts, yielding components that are 1.4 times stronger than ABS. The company demonstrates printed brake handles with patterned strands of fiber embedded within. They have produced custom tools with wrench capabilities in nylon that are stronger than steel.

Like the other hardware manufacturers, they too see this as a three-legged stool, with material

Markforged Metal X system

science, and advanced software design tools blended with the hardware. The company has developed Eiger, what they call the world's most advanced 3D printing software. This cloud-based system can send parts to printers straight from your browser.

Like HP, Markforged has made the commitment to the commercial production of 3D metal printing solutions and have launched the Metal X system, which has the ability to produce fully functional metal parts in under 24 hours.

Currently, they are printing 316L stainless steel components. The company demonstrated the creation of a camshaft sprocket with the strength and hardness of 17-4 PH stainless that can withstand functional tooth interaction.

Andrew indicated that in reasonable quantities, these parts can bring production costs down as much as 98% over traditional casting and CNC machining.

Markforged has also been one of the few to develop a safe metal sintering process that doesn't require a hazmat-enabled environment to produce the parts. The powdered metal materials include a plastic binding agent that can be reduced through a washing step before being sintered in the system's oven. The software actually scales the size of the part proportionately so that when the binder is removed, the part's dimensions become true, and the component becomes solid metal.

In our discussion, Andrew let it be known that one client is actually in the bicycle market and is working on some advanced carbon fiber components for triathletes to reduce weight and increase aerodynamics.

The Metal X system includes 3 components and has an estimated price of $125,000.00 to produce the metal parts. The Markforged X7 industrial desktop system is designed for all non-metal filament printing and runs in the $65,000.00 per unit range.

Printing Is One Thing, Finishing Is Another

By comparison, items that are produced through the injection mold process do come out with a better surface finish. The curves are smooth and seamless, as are the flat surfaces. The reality is that for even the highest quality 3D sintered part, there can be a subtle stipple effect or slightly visible layer steps.

This is why we reached out to Steven Schneider, of Kramer Industries, Inc. to look at the next step in finishing a three dimensional printed part.

Based in New Jersey, this company has been in the part finishing business since 1911 and specializes in the tumbling technology that through automation can create different degrees of finishes on all types of materials including wood, plastic, and metal.

The best way to think about this method is to recall how in the arts and crafts world, stones are placed in a rotating canister with varying degrees of abrasive materials and like your clothes dryer, spins for hours to change the finish. Depending on the required finish, this process may require changing the abrasives to a smoother material.

Kramer has spent years developing their abrasive inventory and has extensive case studies showing the results on all types of materials. They have substrates to cut heavily into surfaces or they can make subtle changes as in the removal of fine layers and then transition to polishing compounds that can brighten parts, with almost mirror-like finishes.

Steven is quite familiar with the exploding 3D print market and turning printed parts into smooth, commercial items has become an important part of Kramer Industries.

When we outlined the business case study, Steven indicated that Kramer would most likely work to develop a multiple tumbling station line where parts exiting the 3D print cycle, end up being loaded into the first finishing stage. “We have the capability to develop both fully automated, and semi-automated finishing solutions. Tumblers with specific abrasives can transfer parts to the next stage through automation, or a single staff member can offload, evaluate and transfer to the next finishing level.”

Kramer has created multiple textures on 3D printed plastics and metal parts that when done look like they have come from a cast mold and have been polished by a buffing wheel.

In seeking to integrate Kramer’s finishing solution into our project, Steven felt that a three station finishing solution with a variety of abrasive inventories and the part transfer technology would take up less than 300 square feet and could be fully operated by a team of two trained staff.

We even spoke of robotic arms being able to collect printed goods from the print beds and could transition them to the first tumbling stage, giving the operation the ability to continue manufacturing overnight.

The total finishing time obviously is based on the desired surface, but we estimated that putting

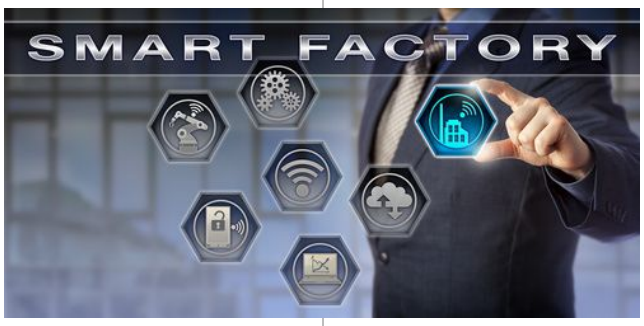
parts through the full solution will take approximately 7 hours.

The Kramer Industries portion of the equipment budget comes in at under $50,000.00 with reasonable abrasive inventory and technical training. What is really important to remember is that all of this is scalable. As production demands increase, adding finishing lines can be factored in. If the processing shifts are staggered, the same labor team moves from one to the other seamlessly.

Repetitive Flexibility

Putting those two words together in most cases would be considered an oxymoron. Repetition is more closely associated with high volume production of a single component. Flexibility means the solution can change quickly to produce something else and is often associated with short-run production.

But the case study outlined here is based on machines, software, and materials that can be used for both higher volume repetitive production, or an almost instant change to print something else entirely.



The 3D printed solutions do not require specialized jigs, or multiple step part handling to cut, form, machine and join to another component. Frame downtubes can present a smooth, polished finish from the outside, but the interior can be filled with a complex honeycomb structure providing massive strength without the additional weight that includes wire and cable chases with smooth bends, and all of this is constructed at once in a hands-free process.

The 3D carbon fiber print process doesn't require manual layups of weaved layers and brushed epoxy resins that are then pressed into a mold or a vacuum bag and then placed into an oven to bake.

Following a Just-In-Time production model, means different part files can be queued and sent to one or a bank of printers. As we alluded to, parts unique to a specific bike model or dealer can be run using different materials and/or colors and with personalization not possible in large volume injection molded scenarios. Most importantly, with such a rapid response, there's little chance for stagnant inventory, which is tied up capital.

With the Arevo bike frames, using a parametric sizing tool within the CAD system means performance shop customers can be custom fit to a frame size that works for them and this can be produced in less than a week. Even the Kupol helmet can have a potentially greater choice in sizes as well as visors and colored inserts without this becoming an inventory nightmare.

Maximizing Time And The Facility

What can't be overlooked is that virtually every component manufacturing printer presents a blank slate each time a file is sent through. From a financially protective point of view, this means the equipment can be utilized to produce other types of parts for non-bicycle clients during shoulder periods. Medical devices, orthotics, even the molds for the Invisalign braces are made on a 3D printer. Ironically, these printers

can actually produce parts to improve your own internal production line.

With the inclusion of robotic arms, redundant routines that remove finished printed parts from the printer bed can extend the production cycle into the night without babysitting.

As multiple engineers have stated, the improvements in both print accuracy and materials will allow continued manufacturing gains.

The model projects that the most labor-intensive process involves the finishing. Final prep, coatings, spray booths, the inclusion of graphics, all require manual intervention. Yet the total production facility can operate on a third of the normal staff and increase the output by more than 40% through a combination of automation and a 24hr schedule.

Feasibility Summary

In the summary of our case study, there were specific conclusions developed:

- The capitalization of the equipment was obviously higher than simply buying completed bikes or the parts in bulk and assembling the bikes domestically. But the tariffs put a significant financial upfront burden each time a shipment arrives. As an example, 250 bicycles shipped in a single container that originally had a net cost of $600 each with an 11% import tariff ($66.00 each) now will have a 36% import tariff with the penalties ($216.00 each) which equals a payment of $54,000.00 before the product arrives in the warehouse.
- If the projection is to produce and sell 4,000 imported bicycles annually at the above import price point, there is a capital outlay of $864,000.00 in import duties up front and there is no ROI on this fee.
- With double production shifts, based on the automation process and a smaller skilled workforce the projected labor costs per part works out to be less than an hourly wage at a fast food restaurant. Actual annual salaries exceed $52,000.00 on average for the facility workforce.
- With the implementation of such an advanced printer farm married to a part-finishing operation constitutes an advanced technology business an in most states would qualify for workforce job training subsidies that could offer as much as 50% of an employee's wage for up to 6 months.
- Not all parts of a bicycle can be produced competitively on a 3D printer. This means that there will continue to be sourcing but the parts purchased will be name brand components or so generic they don't affect the unique aspect of the finished bike. Also, the components are readily available from non-tariff penalty countries.
- Pricing can be competitive when compared against performance level products. Also, part margins will be higher than re-distributed items. In addition to the "Made In The USA" moniker, additional integrated IP can be factored into the pricing.
- Potential market share within the U.S. can offer a reasonable return, but the big question will be whether there is interest within the EU for American made components.
- The entire operation is scalable. Adding printers can increase the simultaneous output of one part or allow for production

diversity. There is no specific jigs, molds or tooling needed to put the equipment into the production cycle.
- Consumables offer a sliding scale of pricing that allows increased margins based on overall volumes.
- Financial institutions are far more likely to underwrite terms for this type of equipment due to the manufacturing flexibility. Additionally, many state incentive programs will allow the deferment of sales taxes on these tools as a motivator to attract the establishment of the company within their borders.

Final Analysis

Like pedal-assist electric bicycles, 3D print manufacturing is here to stay and is projecting to fundamentally change the way we produce parts. Granted, there will always be an emerging market with previous generation technology and/or product features appear in lower cost components, but the uncertainty of trade skirmishes and geopolitical attitudes can have a debilitating effect on a business's projections.

Taking the leap into advanced manufacturing for any industry, but especially for the bicycle market means you must invest in rapid design and engineering. Parts of today will be quickly outdated with improved structural techniques, more advanced materials and such a short window from concept to production. The ability to produce working prototypes in a month wipes away the traditional lead times, forcing brands to measure customer feedback quickly as they prepare to go to market.

For non-manufacturing entrepreneurs, 3D printing as a manufacturing base requires an accelerated learning curve and remember we are talking about an industry that was born just over 10 years ago so there is not a massive historical resource to draw upon. But the rate of acceleration through advancements makes this a logical step towards profitable, agile manufacturing and well worth a deeper look.

Company Resources:

Arevo Inc.
2090 Duane Avenue
Santa Clara, CA 95054
408-780-3993
www.Arevo.com

Formlabs Inc.
35 Medford Street, Suite 201
Somerville, MA 02143
617-702-8476
www.Formlabs.com

HP Inc.
1501 Page Mill Road,
Palo Alto, CA 94304
650-857-1501
www8.hp.com/us/en/printers/3d-printers.html

Markforged
480 Pleasant Street
Watertown, MA 02472
866-496-1805
www.Markforged.com

Kapol - Kickstarter campaign
https://www.kickstarter.com/projects/kupol/kupol-reinventing-the-helmet-with-3d-printing

Kramer Industries Inc.
140 Ethel Road West, unit U
Piscataway Township, NJ 08854
732-650-9599
www.KramerIndustriesOnline.com