Improving Productivity in Additive Manufacturing Operations

White Paper

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Introduction

Historically AM manufacturing has been limited to low-volume, high-cost or high-complexity parts. Poor productivity of AM systems is the primary barrier to wider adoption of this transformative technology. The cost of additive manufacturing is relatively high, with the equipment accounting for > 50% of costs due to low build rates. Variability in the 3D printing of products has been a major concern of management for decades. Production engineers and managers pay special attention to product consistency with respect to dimensional accuracy and material properties such as porosity, strength, temperature, and chemical resistance. However, the most critical factor in a company's decision in investing in new production equipment is productivity and cost per sellable product. Productivity is the ratio of output to input (Productivity = Output / Input). It can be calculated based on equipment, labor, material conversion or some combination. It is typically expressed in unit terms, and is calculated based on a fixed time period (hour, day, year, etc.):

Productivity (unit/machine/hr) = Quantity Sellable Units Produced per Machine (or per Laborer)

For Additive Manufacturing, unit measures are not always meaningful since each unit may be a different size and shape. In this case it is useful to base the calculation on mass of sellable product.

Productivity (mass/machine/hr) = Mass of sellable product per Machine

Another method would be converting all inputs and outputs to economic terms. This allows productivity to be calculated based on the entire operation and can incorporate interactions with labor and material costs. This method is equivalent to Return on Investment.

Productivity (ROI) = Value of Sellable Products / (Equipment Depreciation + Labor Cost + Material Cost)

- Sellable products are those which meet customer requirements, and the value of those goods might be affected by intangibles such as lead time, quality data, design guidance, or other services.
- Capital Depreciation for AM includes the 3D Printer, but also required post-processing equipment. It is influenced directly by the speed and size of the printer which relate to the number or parts which can be produced in a day.
- Materials costs for AM often require a different calculus than traditional manufacturing. Costs per kg are often higher but buy-to-fly conversion is often much better. Scrap depends on equipment and process reliability, as well as DFM robustness. Additionally, many AM processes have hidden material waste streams which may depend on the material characteristics, geometries produced, and post-processing methods used.
- Labor costs for AM include file preparation, machine loading/unloading, and post-processing. Labor costs depend heavily on equipment productivity, automation of both hardware and software, and the specific post-processing requirements of each part.

Barriers to AM Productivity

Slow build rates: Various inefficiencies in the process resulting from prototyping heritage. Building time depends on the height of the part in the building chamber.

Complex application design and process parameters: A considerable amount of effort is required for setting up complex materials, processes, and other parameters.
Limited component size: Size of producible component is limited by chamber size.

Design for AM: Several factors such as build orientation, envelope utilization, and post-processing labor complicate the productivity of AM. Fully utilizing the build chamber reduces the per-unit cost significantly. Additionally, value created using design freedoms of AM to improve part utility or performance is often left on the table.

Availability Loss: Includes all events that stop production for an appreciable amount of time (usually several minutes). Examples include equipment failures, unplanned maintenance, material shortages, and changeovers.

Performance Loss: Includes all factors that cause the process to operate at less than the maximum possible speed when running (including both slow cycles and small stops). Examples include machine wear, jams, substandard materials, and misfeeds.

Quality Loss: Includes productivity lost from manufacturing parts that do not meet quality standards after the first production pass. This includes both scrap and parts that require rework. Rework is often necessary due to poor surface finish and excessive support structures. Component anisotropy, surface finish and dimensional accuracy may be inferior, which requires post-processing.

How to Improve AM Productivity

Some of the areas to focus on for improvement of productivity in AM operations include:

Parts per build: The size of the build envelope and the utilization of this envelop both have an impact on the cost of an additive manufactured product. The size of the build envelope has two impacts. First, products can only be built to the size of the build envelope, which means that it might not be possible to build some products using additive manufacturing technologies without enlarging the build envelope. The second impact of the build envelope is related to utilizing the total amount of build capacity. A significant efficiency factor lies in the ability to exhaust the available build space.

Build Time: Build time is a significant component in equipment depreciation cost.

Labor: Labor tends to be a small portion of the cost to operate a 3D Printer. Labor might include removing the finished product or refilling the raw material among other things. You can estimate labor at 3% of the cost. However, the cost of labor can go up exponentially if there each build requires extensive file preparation or post-processing.

Product Complexity and Quality: There is more geometric freedom with additive manufacturing, and it creates more flexibility; however, there are limitations, as some designs require support structures and means for dissipating heat in production which can negatively impact quality and speed. Typically, there is a tradeoff between print quality and speed with traditional 3D printers due to the limitations of their build technologies. This degradation of quality with increased speeds have constrained companies from building more complex parts and parts with tighter dimensional accuracy requirements with 3D printers.

Material Losses: Each AM process has material loss that may be difficult to estimate, such as photopolymers washed off in solvents, or powders that have become aged or lost to filters. More easily predictable are the material used for supports or scrapped as a quality reject.

Full AM efficiency means that a production process has achieved the maximum amount of output that is physically achievable with:

- Its current technology
- A fixed amount of inputs
- The elimination of technical and organizational inefficiencies

All of this needs to be accomplished without increasing total cost of ownership (TCO).

Benchmarking AM production processes - In production economics, comparisons of productivity measures for specific production processes can help to identify inefficiencies. Useful measures include sellable mass converted per unit time, material conversion rate (or buy to fly), and labor hours per unit or per mass.

AM-Specific Materials - Materials require preparation, and often need postprocessing. Development of new polymers designed for AM applications can help expand material productivity, lower feedstock costs, and improve performance of AM components. For instance, lower viscosity resins result in less waste during cleaning, or powders formulated for high recyclability.

Dimensional Accuracy – Most AM processes result produce parts with a tolerance of ±0.25% of feature size. When tighter tolerances are required, the part may require a secondary process like machining or a unique build orientation.

Increased Total Build Volume and Net Utilization – Due to the limitations of traditional build engines, there is a degradation of the quality of the part and surface finish at the outer boundaries of the build plane, causing inconsistency of the curing process. To increase productivity, it is critical to deliver consistent curing across the entire build plane to increase the yield and net utilization of the build volume.

Increase in Quality Build Speed – There has traditionally been a tradeoff between build speed and quality of part production. It is critical to balance speed with quality part production to maximize build throughput. This is done by mastering the process physics then creating equipment architecture and software to control the process determinately.

Reduction of Post Processing Time – Poor surface finishes, excessive support structures, incomplete curing, complex part geometries and more impact post-processing time. Typical post-build curing can take more than an hour depending on part geometry and materials, and the quality of the build. To increase productivity the quality of the part produced during the build must improve, the amount of support structures needs to be reduced and the post-build curing process time must be minimized.

Intelligent Build Optimization Software - Artificial intelligence (AI) and machine learning (ML) are enabling AM production consistency. AI and ML software optimizes the configuration of materials, design features, printer settings, printing processes, and environmental conditions for making a product. These technologies can create production feedback loops that automatically eliminate defects as printing occurs and can significantly reduce inconsistencies of outputs across printers and over time. It looks for factors that can help achieve higher consistency, yield rates, cost savings, and any dimension of quality based on material choices, machine parameters, and even part geometry to achieve the goals selected for optimization.
This level of visibility and control allows them to achieve higher yields and greater repeatability for many types of products without the need for postprocessing (refining the product after it has come out of the 3D printer).

How Nexa3D Delivers 20X AM Productivity Gain

NXE 400 breaks industry speed and size barriers with its 17L build volume, intelligent build optimization, and Nexa3D's revolutionary patented LSPc technology delivering 6.5X the speed.

Fastest Print Speed with Quality – NXE 400's delivers build-up rates for production speed at highest quality level. NXE 400 is 6.5X faster than other AM printers. Uniform exposure and process control ensure production build speeds at the highest quality levels.

Largest Build Volume - Nexa3D's The NXE 400 features 2.5 times greater build volume (17L) compared to currently available technologies, allowing for much larger parts, higher part throughput, and ultimately lower part cost, all with the higher-resolution pixels (76 µm) and isotropic prints.

Build Optimization Intelligence - The NXE 400 is designed with user friendliness and automation readiness in mind including active resin management, easy to change materials, automation ready access and plug and play user interface. Its cognitive capabilities facilitate optimized prints and offers complete automation from print to product. AI and ML powered cognitive software and integrated sensors technology, which together optimize manufacturing part performance, provide detailed predictive diagnostics and offer continuous monitoring.

Nexa3D's internally developed intelligent software connects our hardware and materials together into a powerful, user friendly system while providing a new era of predictive and prescriptive service.

Speed and Quality Balanced Materials - NXE 400 printer comes equipped with unique materials that are tailored for ultra-fast printing of functional prototyping, production tooling and full-scale manufacturing of end-use parts, casting patterns and dental restorations.

Consistent Quality Build Engine - Nexa3D printers are powered by the company's proprietary Lubricant Sublayer Photo-curing (LSPc) technology and patented structured light matrix that in combination are capable of reaching speeds of 1Z centimeter per minute. In addition to our highly reliable LSPc technology. Maximizing the yield on build volume.

Machine Reliability and Availability - Most notably, we designed the NXE 400 for complete user self-reliance, ensuring that our customers can service every aspect of the printer in minutes based on prescriptive analytics and user replaceable modules. The NXE 400 is crafted to be completely modular in design for easily interchangeable parts and technology upgrades eliminating hardware obsolescence.

Consistent Washing – xClean washing solvent reduces time lost to change over, costs required for handling of highly flammable solvents, and disposal costs. All this while providing consistent washing performance compatible with all standard washing techniques, resins, and equipment.

Rapid "Perfect Part" Curing - xCure combines heat and dual wavelength light consistently to post-cure printed parts using a combination of material specific prescribed sequences in a controlled chamber. xCure is designed to process the entire print envelope of Nexa3D's NXE 400 printer. The chamber can accommodate up to three build plates at once and allows parts to cure directly on the build plate or be placed in a basket and cured individually. xCure is equipped with high power LEDs that operate at dual wavelengths as well as in sequential UV and thermal curing modes. xCure comes pre-loaded with validated workflow curing recipes for all approved Nexa3D photoplastic materials and is easily upgradeable for additional materials.

Post Processing - Part finishing is an ongoing area of research. Typically, parts used in high volume applications are designed to minimize final finishing work and enable automated finishing processes. Automated finishing solutions have typically been bespoke for the application, however Nexa3D has been a pioneer in minimizing post-processing requirements and developing automated solutions.

NXE 400's 20X Productivity Gain Equation*:

(6.5X Z-Speed) x (2.5X Build Area) x (1.3X Post Processing Productivity) = 21X parts/printer/hr

** Productivity gain can be greater than 20X depending on material and part complexity*

Nexa3D is 100% focused on AM productivity increase to enable all manufacturers to:

- Increase number of parts per build
- Reduce total build time
- Increase AM production rate per hour and hours is production
- Reduce Build Setup time and post processing time per build
- Increase material yield per par and usable parts per build
- Reduce the amount of material for supports and post-processing requirements

Nexa3D's technology is breaking the speed barrier by actively overcoming the traditional speed limiting factors of traditional SLA without compromising accuracy and resolution. Streamlining our software more making it easier for everyone to use – we optimize max speed, part success, and accuracy of every print.

Get In Touch

Our experts are here to support you.
Get in touch today - we will be right with you.

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