The Truth About Speed

IS THE HARE REALLY THE FASTEST?

By Rob Winker, Stratasys, Inc.

Speed is a fundamental advantage of 3D printing (or additive manufacturing) that is critical in the race to bring new products to market. When asked, most all of those performing 3D printing will say speed is important. But how fast is fast enough, and how is speed measured?

In reality, speed is a relative measure, and when it comes to 3D printing, it is throttled by many variables. To lump technologies in “fastest” and “slowest” buckets is misleading. While some generalizations are fitting, few hold true when considering the entire speed picture.

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And the perception of speed — as a print head zips across a powder bed or a laser dances along a vat or an extrusion head methodically works its way around a part — may lead you to the wrong conclusion. The right conclusion considers the total process time, degree of automation, settings that throttle speed and change in build speed over time. And it pairs this information with the desired mode of operation.

What product designers and manufacturers really want is an efficient process: one that has few bottlenecks, lots of automation and rapid response. To find that efficiency, understand your operations and learn the truth about 3D printer process time.

THE WHOLE PROCESS

Build time — the time a part spends in the machine — is the mostcited measure of process speed. But it is just one component of the elapsed time for part completion.

The tortoise and hare fable offers a good comparison for 3D printers. A quick dash does not mean that the hare crosses the finish line first, because that sprint does not cover the entire distance. In this analogy, build time is just one leg of a much longer race to deliver parts. The 3D printing process has many phases, including file preparation, system preparation, part building, postbuild machine operations and post-processing for parts.

To measure speed, you must clock the entire process: Start the timer the moment you receive an STL file, and stop it when the part is ready for use. As shown in Figure 1, a four hour build plus additional required steps can result in a 12-hour

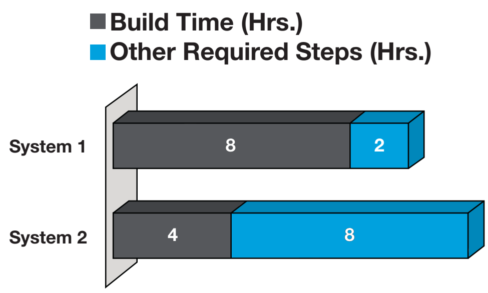

Figure 1

overall process. Conversely, an eight hour build plus other required steps can result in only a 10-hour process. So the process with a slower build stage could be the overall faster process.

Possible front-end steps:

- Orient model
- Generate supports
- Select layer thickness
- Apply build style
- Prepare machine
- Load or swap materials
- Warm up machine

On the front end, the time to create a job — orienting, supporting, slicing and applying build styles — will vary, especially if stock build styles do not apply. But the big surprise to many is how much time may be needed to prepare the machine, load or swap materials and warm-up the machine, especially if from a cold start. Before kicking off a job, you might need to wait anywhere from a few minutes to several hours.

Possible post-build steps:

- Wait for post-build idle
- Drain parts
- Wait for binder to harden
- Wait for chambers to cool
- Clean
- Wait for post-curing
- De-powder
- De-cube
- Support removal infiltration

On the back end, after the build finishes, two factors come to play: post-build idle and post-processing.

After a part is built, depending on the process, parts may have to drain, binders may need time to harden or chambers may have to cool. These delays vary from no time to many hours. For some technologies, build time is effectively doubled because parts have to cool for nearly as long as they were building.

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Once you can handle the parts, it's time to post-process them. Every technology requires some form of post-processing, and the time to complete this step varies widely. For an accurate sense of delivery speed, you need an understanding of the actions needed. Depending on the process, these steps might include cleaning, post-curing, de-powdering, de-cubing, support removal, infiltration sanding or other steps.

FDM start to finish:

With single-click, automated build preparation and an idle, ready-togo 3D printer, your parts will be building in 10 minutes on average. When the build is done, there's no waiting for steps like cooling, drying or hardening. It's straight to the support removal process where you have the option of an automated dissolve process.

FDM: Tortoise or Hare?

"The perception of speed — as a print head zips across a powder bed or a laser dances along a vat or an extrusion head methodically works its way around a part — may lead you to the wrong conclusion."

In the excerpt above from this white paper, FDM® (fused deposition modeling) is the methodical process. While overall process speed is competitive with other technologies, the speed of its build phase isn't as fast as the laser or the print head. Looking only at the build-phase step in the process would give the wrong impression of FDM.

AUTOMATED OR MANUAL

For those who are resource-thin, also consider the impact of labor-dependent processes on delivery time. What delays will occur if personnel are not ready and waiting? And how much time will they need to complete the action? For every manual step, without resources at the ready, delivery time can swell. This can become a critical factor and a bottleneck to delivery.

The advantages of automation are most notable in the postprocessing phase. For example, a 3D printing technology that spits out dozens of small, highly detailed parts in a few hours may have delivery time measured in days if each part requires more than a few minutes for support removal and finishing.

An operator at an FDM-based Fortus® 3D Production System.

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This scenario becomes even more burdensome and time-lagged if a skilled technician is needed. For example, removing supports made of the same material as the part is not a job for an unskilled staffer. It takes an experienced hand and keen eye to discern where the part stops and supports begin.

If your resources are so thin that you will be doing all this postprocessing yourself, you have to consider whether you have the time to take on this work.

Automation:
No bottlenecks; no delays. With automated build preparation and an FDM 3D printer loaded with material and soluble supports, the process is almost entirely automated. From start to clean part in hand typically requires five minutes or less of direct labor.

BUILD TIME VARIANCE

Build time is a function of many variables, some that you select and others that are fixed. In the fixed category, consider the details of the parts. It is widely known that the height of the part drives time: For every technology, the taller the part, the longer the build time. But many overlook other factors, such as material volume, surface area and part footprint and configuration. Each might add hours to build time.

There are too many factors to cover, and they vary for each technology. To learn the truth about speed, you should discover what affects time and how that translates to your parts. Note: Be cautious. Those who want to sell you a system know what increases time, and they may attempt to redirect you to a part with the fastest build speed.

Some of the variable elements of build time come from the build styles you will use. Do you want high resolution, smooth surfaces, solid parts and the best mechanical properties? Those will take more time. The only way to fully understand this component of speed is to discuss the part qualities you will need, match them with a technology and ask for an estimate of the resulting build time.

Take FDM as an example. With the high-end systems, the software offers control over slice thickness, extrusion diameter and the number of contours (boundaries of each layer profile). Altering any one of these variables will change the build time. Another FDM example is the fill style. If you opt for a sparse fill — solid boundaries with an internal lattice — you can reduce build times by as much as 60 percent. See Figure 2.

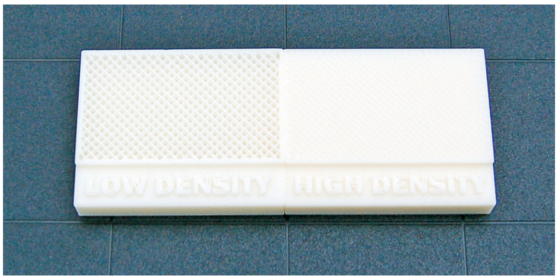

Figure 2

The two remaining user-selected variables that affect time are part batching and part orientation. If you plan to hold postponed builds until you have amassed as many parts as possible, you will want to understand the effect on time. Likewise, if you will build individual parts as needed, find out how that affects time. Some technologies are fastest on single part builds while others require multi-part batches to realize the fastest times. See Figure 3.

Figure 3

Some Variable Elements Affecting Build Time:

- thin layers
- high resolution
- smooth surfaces
- solid geometry
- best mechanical properties

Part orientation has a direct effect on part quality as well as time. As stated previously, taller parts take longer to build. But recognize that orientation is not always at an operator‘s discretion. Most 3D printing technologies put their materials through a state change, such as from liquid to solid, which induces stress. Some cope with residual stress better than others. For those that may twist, warp or curl, the shortest part dimension may not be an option for the Z-axis of the build, so you may be forced to build the part in a different orientation. This makes claims of half-inch per hour rates, or similar, misleading. For example, a long, flat part may have to be built on edge to keep the part from warping. Due to this change in build orientation, what could have been a one-inch tall build (one hour) becomes a four–inch tall build (eight hours). See Figure 4.

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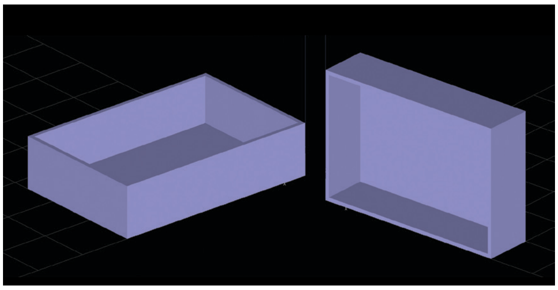

Figure 4

Build speed:

FDM can produce a nearly hollow, lightweight part with great strength in less time than it takes to make the part solid with conventional processes. And unlike other 3D printing processes, it can do it without headaches, such as evacuating powder or resin from within. FDM is unique in this ability.

Batching:

FDM won‘t penalize you for building one part at a time, but you can shave off some time when combining parts in a single job. So, you decide how you want to build them: one-of, as needed, or in batches.

Orientation:

Yes, taller parts take longer, but the orientation is entirely up to you. FDM will build a good part no matter how you position it.

TIME’S EFFECT ON SPEED

Also like the tortoise and hare, some 3D printing technologies start off fast when the machine is fresh and new but slow down as their components age. Others may have a slower, but consistent, process speed over the life of the machine.

For example, laserbased processes may see increased build times as power output declines. Less energy means more time. Another example of the ravages of time is aging materials, which is especially true with systems that reuse materials by regularly combining new and used. Material that surrounds parts as they are building has been exposed to energy, heat and moisture, all which can change the reaction properties. So a one-year-old bed of powder may take longer to solidify into the part you desire than it did when the material was fresh.

Consistent throughput:

Build two parts of the same design — one today and one five years from now — and get the same speed performance. FDM‘s throughput is consistent. It doesn‘t slow as the machine ages.

TIME BUCKETS

While it is comforting to know that a technology can deliver in a hurry when emergencies occur, the truth is that you will likely fall into a pattern of 3D printer operation. For example, you may hold jobs until the end of the day to make sure that all the day's parts make it into the overnight build run with the goal of having usable parts first thing in the morning.

If you believe that you would fall into this pattern of use, then the difference between a four-hour build and a 10-hour build is not very important. Both options will be ready with parts when you walk in the next day. Now, the differentiating factor becomes how long it takes to post-process those parts.

In general, 3D printer users typically fall into one of three build patterns: four-hour cycles (half a workday), eight-hour cycles (full workday), and overnight cycles. So the question of speed should be whether or not your typical parts can be completed in your anticipated operational mode. Before settling for a fast build with moderately acceptable properties, consider what approach will be your most likely.

As you can see, there are far too many variables to declare any technology the fastest for all parts. There are too many factors to definitively state which is the tortoise and which is the hare.

The truth is that you need to know your operations, your parts and your requirements before measuring speed. And of course, remember that an inferior part done quickly can never outperform a superior part completed in a bit more time. Build speed should be just one of the many considerations in your selection of the right 3D printing technology.

Time buckets: Build single parts throughout the workday as needed and batch a bunch of parts for an overnight run. By 8:00 a.m. the next day, you can have as many parts with FDM as you would from any other 3D printer.

info@stratasys.com

STRATASYS.COM

HEADQUARTERS
7665 Commerce Way, Eden Prairie, MN 55344
+1 888 480 3548 (US Toll Free)
+1 952 937 3000 (Intl)
+1 952 937 0070 (Fax)

2 Holtzman St., Science Park, PO Box 2496
Rehovot 76124, Israel
+972 74 745-4000
+972 74 745-5000 (Fax)

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