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# Get the facts on the mechanics, geometries and physics of large additive parts


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Metal additive parts for commercial applications come in all shapes and sizes, and since the introduction of our M Line system, critical parts can now be made accurately on a much larger scale. One of the lesser talked about technical areas within additive is how the mechanics, geometries and physics of the build can affect the outcome of the part.

From a purely physics standpoint, there is no technical difference in the effects that are observed during a build based on if the part is small or large, but there can be visual and geometric differences with larger parts because the dimensions can make the differences more significant.

Rob Dean, AddWorks Leader in EMEA, GE Additive, discusses the role fundamental principles play when making a part, how these are manifested in larger parts, and how any potential issues can be tackled.

**Q: What's different when printing a large part? Are the physics the same?**
The physics are identical regardless of whether a large or small part is being printed, and the terms large and small are subjective anyway. The physics are also the same if you're using one laser or four or if you're using a 100 mm or 500 mm build platform. Similarly, the layer-by-layer physics and the scan- path physics are also identical. There are no new skills that one needs to acquire to be successful when printing large parts.

**Q: Why is noise made about large parts?**
It is because when you have larger parts, they are dimensionally bigger. So, a relative movement and growth of 1% when something is 10 times longer equals a 10 times absolute difference.

Accuracy is an absolute measurement, so you may have the same measurable movement on a large and small part, but the absolute movement will be much greater on the large part. You also need to control the large parts to a smaller relative movement to achieve the desired result.

While the physics are the same, you do need tighter controls for larger parts. The small percentage deviations that you might be able to get away with on mid-size machines, you can't get away with on the larger machines, and these can become problems if you're not aware of them.

It is worth mentioning that these larger absolute differences are not machine driven; they are driven by the part itself. If you put a small part on a larger machine, you will get the exact same result as on the smaller machine.

The larger movements come from the mechanics of the part itself. So, as the part gets very hot, layer by layer, it grows in size. Similarly, as you cool it, it shrinks a little. This is not linear and the amount the part changes differs from part to part. We can apply linear scaling on the machines used, but any non-linearities that cannot be dealt with at a machine level are driven by the part and need consideration by the component or build job designer.

**Q: How do we help our customers to scale up from the mid-size machines to the larger platforms, while ensuring that the physics of the new printing scale aren't causing issues?**
Our M Line build platform is essentially four of our mid-sized M2s. So, if you put the same part four times on an M Line, you can expect nothing to be different. If you're trying to make a part that is four times bigger, that is where the absolute values will make a difference.

The forces that come from the process - such as heat input and cooling during the process - can cause it to grow non-uniformly, so they need to be considered. As larger parts attempt to distort, the greater forces that arise from this process in the part can also cause cracks—in the part or the build plate—causing the parts to pull off the build plate, or pull up during the printing process and hit the recoater blade. So, it is not just the distortion of the final, cooled part the build job designer must consider.

However, those users who are looking to deploy the M Line tend to be experienced users of additive and already have an application in mind. We can look at their parts ahead of any issue manifesting itself and help them understand where the focus should be in terms of preventing the issue. We can also help to develop appropriate solutions—all before the machine leaves our factory.

In this process, we look at the root causes of any issues in their part or build job—be it heat build-up, stiffness of the part, or non-linearity of shrinkage—and explain how we can mitigate these effects. This fundamentally boils down to managing the heat during manufacturing or physically constraining the movement during either heating or cooling.

We work directly with our customers to find the best solutions for them. There are several tools they can use—such as adding supports, tuning the heat input, or compensating the geometry—none of which are new concepts, and a solution typically involves utilizing several of these tools. This involves finding the best mix between addressing root cause and treating the symptom, depending on the part's technical, quality and business-case requirements.

**Q: Are we applying our learning from the aerospace sector to ensure that the M Line is ready for widespread commercial use?**
Our machine development team, design engineers and the simulation team at GE Additive have been working closely with the GE Aviation product and manufacturing teams to deliver user-driven developments and solutions for the M Line. In conjunction with our colleagues at GE Aviation, we use common tools to understand the challenges and mitigate them.

Working with the GE Aviation team has allowed us to talk a lot more about the process, because they have significant experience on mid-sized platforms, as well as component and product functional requirements. Bringing this directly into our working relationships has ensured the M Line can target real-world requirements.

For example, working with the simulation team, we can look at how the heat comes in during the process and adjust the parameters and supports and adjust the build job to ensure we get the results the part needs. This has driven us to develop a machine platform that enables the end results to land within the required quality window.

Many additive users still develop their production process by printing parts to see what happens. While that trial-and-error approach is fine on a mid-size platform, it is too costly and time consuming on a large platform. However, because our platform is designed to operate in a specific way, and to control the process to the same part requirements we previously developed for our M2 platform, we can realize much of the development work on the smaller, faster, and lower-cost M2 machine. On the M2, we can validate any issues and their root causes and introduce any corrective actions. Once a solution is in place, we then print the part on the M Line.

This is important as the M Line is not a development machine, it's a production-focused system and you want to bring mature work to it. Working with our colleagues at GE Aviation, and having that very strict user-driven view of machine development rather than the machine developer's view has helped us deliver a consistent user experience between our platforms. The ability to transfer between platforms hasn't been possible before, and because the development is user-driven, we can transfer the parameters from an M2 to an M Line without having an enormous transfer exercise.

**Q: There are comments around that a thicker build plate (10 cm or more) ensures better part geometry at large scale. Is there any merit in this?**

There is some merit in it. We know from our X Line and some mid-size platforms that if you put a big part on the build plate (relatively speaking) and increase the relative stiffness of the part versus the stiffness of the build plate, then it can pull up the build plate if you do not manage the heat build-up in, and residual stresses from, the part.

The build plate is essentially stiff but still has some flexibility. As the forces increase with the increase in part size, if you don't manage those forces, you can end up with forces that want to cause a certain distortion and a part stiffness much greater than your build plate stiffness. This can subsequently distort the build plate. One solution is to increase the thickness of the build plate to 10 cm or more.

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However, this a very costly solution and not sustainable for commercial manufacturing. While valid, we have never had to resort to this solution and do not expect to in the future.

A better, more cost-effective solution is to use simulation software to understand where the distortion forces are coming from, understand their root causes, and subsequently mitigate them. Plate distortions are something to be aware of and exist just as much in mid-sized and small format platforms, but it doesn't stop us making parts. In some cases, you adjust the build job design to manage and control the heat. In other cases you change the geometry of the part. It is something that we work with our customers on to find out the exact needs to stop it from happening during their build, without the need to buy a costly build plate.

**Q: How do we ensure that larger parts aren't affected by the larger absolute physics values?**
You need to be aware of the physics going on when you make your part, such as how the heat is coming in during the build and how you're managing that with the supports. If you can keep it uniform throughout the build, there will be no major issues beyond those that have been acceptable on a mid-size platform. But it does need consideration and thought.

The difference between the M Line and the M2 is that you need to consider the physics all the time. For example, in large builds, supports play a larger role than just manufacturability, as you can use them to manage any thermal gradients in the part where the hot and cold regions meet.

The main point is that it's not the machine that can cause issues, it is the part itself. The M Line is easy to use, because it builds large parts in a predictable and repeatable way—due to its uniform gas flow—so any simulation solutions can be integrated easily.

**Overall Outlook**
While the mechanics, geometries and physics of larger parts need to be considered to ensure that you don't run into unexpected issues, they are not driven by the machine but by the part itself. Each part will behave differently. The best solution to tackle any issues is on a case-by-case basis using a combination of technical results and a business case that is unique to your part and application.

One of the key things to note is that there is nothing new here, and these are phenomena that we see at all build scales. We see it, understand it, and control it on the M2 and because the M Line is a user-driven extrapolation of the same requirements that drove the development of our M2, we can do the same at larger scales. We're just working with larger absolute magnitudes.

*If would like to know more about how our technical teams can support as you scale up on your additive journey? Get in touch.*