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Get the facts on stability

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Stability is something that needs to be tested at all stages of additive machine development to ensure printing success. Depending on the user's level of exposure to additive, the concept and interest in stability can range from being an unknown to being a commonly discussed factor when printing.

Maintaining a high level of stability at all stages of development ensures that you get a higher quality part that is less prone to defects and has the intended material properties.

Here, Sarah Ulbrich, lead engineer – process & materials development at GE Additive, discusses how stability is being achieved on the mid-size M2 machines and on the larger M Line system.

Q: What is Stability?
There are three types of stability to consider. The first is platform stability. When we look at platform stability, we are testing across the platform and across the optical field in all dimensions. In these tests, we investigate all the different angle incidences from the lasers and test for material properties.

The second stability that we test for is the build-to-build stability. This is performed on just one machine, and we build the same print job repeatedly to confirm that we can continually reach the same stability.

The third stability that we look at is machine-to-machine stability. This is where we have different machines of the same platform, and the same build job, and we test them over and over again.

Platform stability is something that we look at from a material perspective during parameter development, then we look at it from a machine perspective. During development, we make sure that we can reach that platform stability, and during machine validation, we make sure that we can reach it across the platform repeatedly.

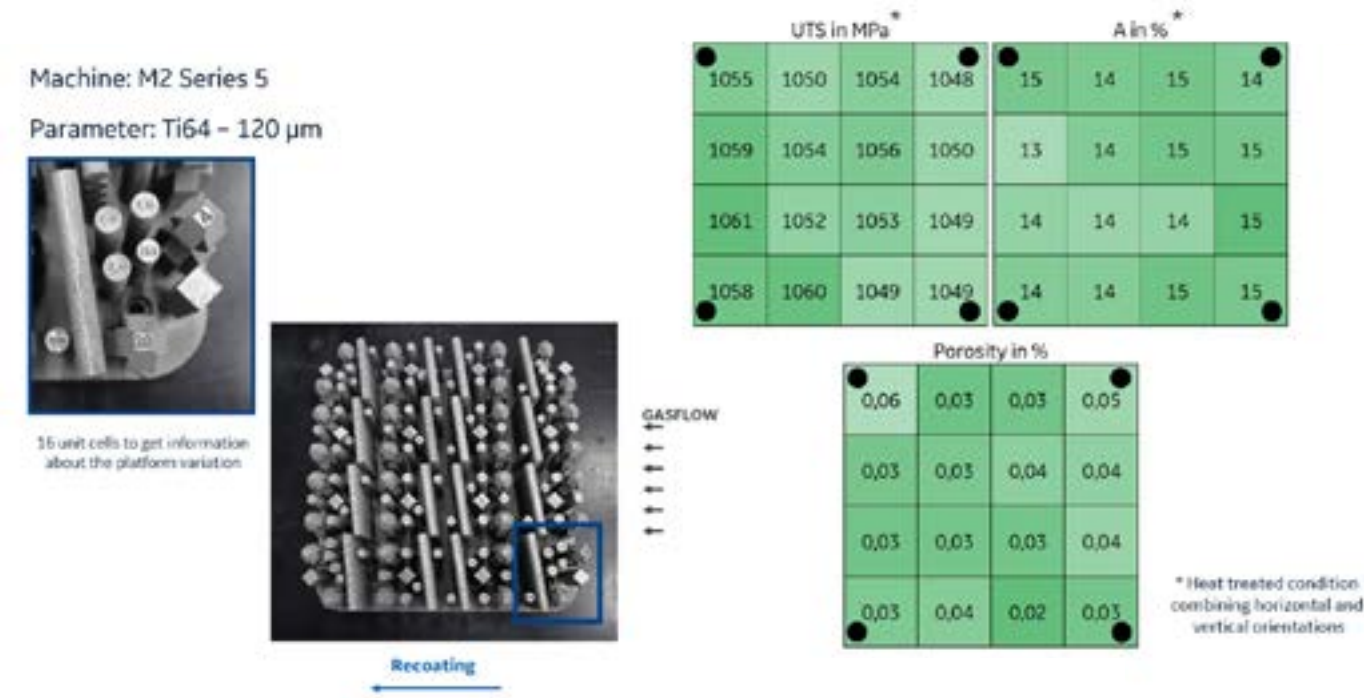
Q: What criteria do you use when determining stability?
We have a set build-job design for the different platforms. While they are similar, and standard specimens are used across all the platforms, the samples are arranged differently on the platform so that we can measure across the whole platform. We then measure a range of properties, including surface roughness on vertical and angled surfaces, porosity, and mechanical properties such as tensile testing and hardness.

There are two groups that can be tested. These are printed parts in the as-built state or in the heat-treated state. For determining stability, we test the parts in the as-built state, because they are more prone to irregularities than parts that have been heat treated. When you heat treat the part, you change the material properties of that part, and any differences get washed out compared to an as-built part. So, if something goes wrong during the build process, it is easier to detect it in the as-built state.

Q: What are we testing, and what results are we getting on the M2?

On the M2, when we test for stability, we have a standard setup where we use unit cells of specimens containing tensile, porosity and surface roughness samples in all positions of the platform and test the properties of the material. These tests are done in both the as-built and heat-treated states because the end-users are more interested in the heat-treated state, but for us, the as-built state is more interesting for the reasons previously mentioned.

M2 Series 5 Platform Stability



Our tests have shown that we achieve very stable results across the platform. These results are also shown on our published material data sheets. We do this for all new developments. [Data sheet]

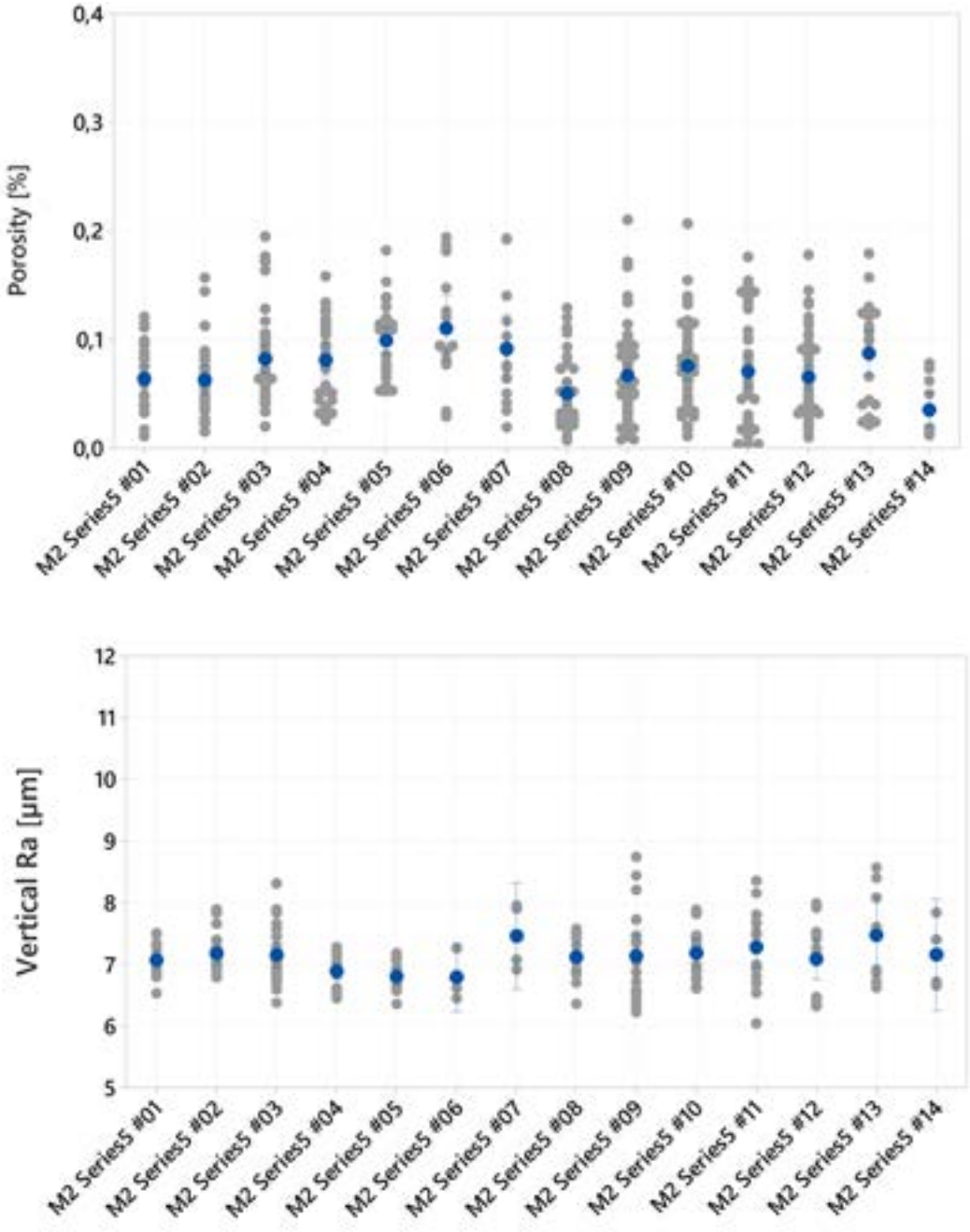


Figure 1: Graphs show repeatable results over 12 M2 Series 5 machines from the factory acceptance test (FAT) for CoCr 50 µm. *Source: GE Additive*

Once this has been completed, we also generate and analyze a lot of data from factory acceptance tests (FATs). From these tests, we have seen very stable machine-to-machine results. For example, we see the results of 12 different M2 Series 5 machines tested with CoCr showing a very high stability.

A key part of these tests is that we don't look only at the sweet spots of the machine be it for best gas flow location or best optic location, but we also look at worst-case spots as well. By doing this, we have been able to identify problems that existed in the past and have rectified them by making the appropriate improvements using the obtained data.

Q: The M2 is a smaller build plate, but the M Line is on a whole different scale. How are you approaching stability on this larger format platform?

On the M2, we have a 245 x 245 mm build area, but we have four times the space on the M Line. To tackle the larger build plate, we quadrupled the number of samples on the plate and placed them strategically according to our laser allocation. This way, we can test all over the platform and at all angles of incidence.

This is our FAT. Additionally we run a capability and stability test to test all the laser angles. We took what we learned from the M2, quadrupled the number of samples, tested them according to our standard lab procedures, and ran the same stability and capability tests that we performed on an M2, but on a larger scale. We also tested the stitching during a standard FAT and during machine validation. This is at both the bottom of the machine and at different heights so that we know the stability over both the platform and height of the build area.

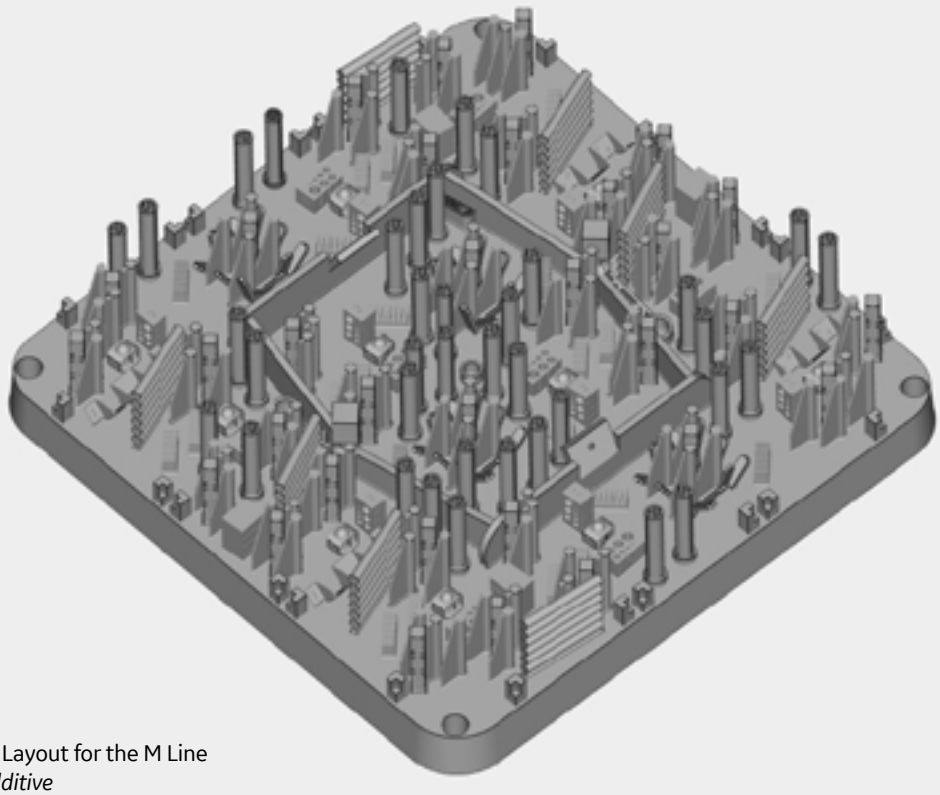


Figure 2: FAT Layout for the M Line
Source: GE Additive

Figure 3: Platform stability of Porosity [%] over M Line 500 x 500 platform for Ni718 50 µm layer thickness; as-built
Source: GE Additive

Figure 4: Platform stability of UTS [MPa] over MLine 500 x 500 Platform for Ni718 50 µm layer thickness; as-built
Source: GE Additive

Q: What does the validation process look like for the M Line?
A lot of testing takes place during the validation process. As the M Line was being developed, we were continuously testing, working closely with our in-house laboratory and quality teams. The same is true during the parameter development stage as well. Since locking in the machine configuration and parameter sets, we have performed 443 porosity, 298 tensile measurements, 780 vertical roughness measurements, and 224 upside/downside measurements. This is in addition to all the other tests that were performed before we locked in everything on the machine.

This large amount of testing has been done in the validation phase so we can reduce the number of tests required during the production stage. We always perform a range of tests on each machine before it is shipped to the customer so that we know they are capable of delivering the expected productivity levels.

Q: What are the benefits of having an on-site laboratory compared to sending the parts off for testing?
The biggest benefit is the time saved by not having to ship the samples off to be tested, losing time in both transport and receiving the results back..

Q: What's next in stability development and how do we get there?
The ideal next step–and it is still some way off–is eventually to get to a point where we don't have to do material testing anymore. This way, we will know the material results by measuring the machine and have confidence that the system will be able to get those results each time. The only way we will get to that point is by continuing to collect more data and more analytics. The next logical step is to start reducing the number of tests that we do, but because the M Line is a relatively new system, we will have to wait a while to start implementing this approach.

Overall Outlook
When it comes to stability, there are several tests that need to be performed to ensure that the machine is working as intended and that you're going to get the desired material properties in your part, regardless of where it is on the build plate. To do this, we need to make sure that the worst-case areas are also being analyzed alongside the sweet spots, as that allows you to evaluate the entire build volume. This means we can continuously make improvements to our systems and machines, but it also enables our customers to have a certain level of confidence that when they use the machine, they are going to get the intended output.

If you would like to know more about how we're committed to stability and how it impacts the other aspects of your printing approach such as the reliability of stitching in the larger M Line machine, get in touch.