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Get the facts on multi-laser stitching validation and performance

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Stitching, otherwise known as multi-laser processing, is a key piece of the additive puzzle when printing larger-scale parts.

While the concept of stitching different sections of a material together might seem daunting to some from a mechanical property point of view, there should be no need for concern as long as your machine manufacturer can provide you the right mechanical data to show that the part behaves as it would if it were being produced with a single laser.

We caught up with Kevin Menger, Additive Process & Materials Engineer, GE Additive and Dr. Benedikt Roidl, Senior Engineer, GE Additive, to discuss stitching and how, with the right kind of preparation and know-how, it is possible to anticipate, avoid and mitigate any issues.

Q: A basic question, but why do we use the word “stitching”?
It goes back to the interlocking of melt pools, which is now an outdated strategy. When you looked at how the two melt pools meet at the point where two lasers meet, it looked like the sections were sewn together like a suture.

Q: Why do we stitch?
There are two reasons that we stitch parts. The first is for a higher productivity and the second is for building large additive parts beyond the build area of a single laser.

On productivity, if we want to build parts quickly, we can use several lasers to reduce the build time of the part. When several lasers are used, we have stitching in regions where the lasers meet to improve the mechanical properties of the part. We can also improve the productivity further with good gas flow—enabling more efficient local exposure regions—and knowing how the soot will behave in the machine.

For producing large-scale parts, users may also need to stitch if the build plate is larger than the optical field size. For example, the M Line has a build area of 500 x 500 mm, but our optical systems have a field size of 400 x 400 mm. So, when building large parts, more than one optical system is required. So, this automatically requires the part to be stitched.

Q: Why is it so difficult to stitch properly?
It's not hard to just stitch, as you only need to let two or more lasers work in the same place, but it's difficult to do stitching well. This is because, from a parameter development point of view, we're dealing with multiple exposure elements at once. On one hand, you have the bulk area, which is quite simple to stitch as there is an overlap area, so it's pretty forgiving . As well, the lasers don't need to be aligned perfectly. The lasers dont't get good mechanical results, when surfaces are machined properly and the part is not used in as-built condition.

On the other hand, it gets difficult when you start to stitch the contour—the outside surface of the part—because you need to balance obtaining a high level of surface finish with little to no sub-surface porosity to avoid costly post-processing steps whenever it is possible.

Stitching in the contour region is unforgiving with respect to the alignment of the melt pools that need to meet each other. It's hard to align these melt pools to achieve acceptable levels of both surface finish and sub-surface properties. If your melt pools are misaligned by more than, say, 50 microns, then you're going to get issues with sub-surface porosity and a bad surface finish locally.

Without any additional control mechanism, it is hard to keep the optical systems aligned within 50 microns over the duration of a build. If the system drifts above this threshold, you start to get surface discontinuities that can cause problems, especially regarding fatigue.

Q: What are some of the factors that can influence stitching quality?
One of the factors that indirectly influence the quality of our stitching is gas flow. If too much soot is deposited on the laser window and not efficiently transported out of the process chamber, it can cause a thermal lensing effect. This causes the laser window to heat up, resulting in a shift in the focal plane, distortion of the laser, and a misalignment of the optical systems.

Another factor might be the recoater blade leveling. So, the way the build is set up can affect the optical alignment. The blade needs to be set up so that it's aligned to the optical plane. The temperature and thermal behavior of the machine can also have a big impact on the optical alignment. A lot of power goes into the machine, so we need to dissipate the generated heat.

We use a cooling system to keep our thermal influences low on the misalignment. It is important that you control this; otherwise, you'll have thermal drift of your components, for example, in the recoater, recoater rail, build level, optics, optics frame, process chamber.

The final main factor is the initial optical system calibration. If a lot of effort is put in to calibrate the optical systems properly before use, there is going to be a solid baseline of alignment in the machine, that is, below the 50-micron threshold, before printing.

Q: Why are recoater leveling and alignment particularly important?
The recoater alignment to the optical calibration plane is important because the optics are set to a certain height where the alignment is perfect. The recoated blade needs to be set up parallel and to the same height as the optical plane so that there is no misalignment. For example, if the recoater is set up higher than the optical plane, it leads to a gap in alignment between the optical systems. Also, if there is a tilt in the recoater blade relative to the optical plane, it could lead to one side of the part having perfect stitching, while the other side is full of defects. If the user of the machine can set up the recoater blade correctly during the initial set up of the machine, as well as follow the developed process given to them, they can have a positive influence on the stitching quality, as well as ensure a high level of stitching consistency between builds.

Q: How does stitching calibration and performance affect the optics?
One of the most important ingredients for good stitching is the initial calibration. First, the individual optical components and their optical fields need to be calibrated, so that they point in the right direction from a single laser perspective.

The second calibration step looks at the calibration of relevant optical system combinations and ensures that each system is perfectly aligned with all the others. You have to bring these interactions within a certain threshold of alignment, the 50-micron threshold that was mentioned earlier. This is the global misalignment across the whole build plate. This is a solid baseline for a good stitching result.

As the optics drift over time, they need to be recalibrated every six months. This is the current guideline, but it is subject to change as it's currently under investigation. We also advise our customers on the software countermeasures that are available to them and how the software is key to obtaining good stitching. With these countermeasures it is possible to go up to a 100-micron threshold and still achieve a good level of stitching results.

Q: So, what does good stitching look like?
If you have good stitching, you hardly see anything on the surface, including any surface discontinuities or different coloring from the thermal behavior of the material during the melting process. Additionally, below the surface, having a level of porosity that is consistent with your single-laser machine behavior is a sign of good stitching.

Overall, a good a stitch will ultimately be showcased if the microstructure of the part is consistent, regardless of whether a single or multiple lasers were used. It is also possible to have something that is discolored, so it looks like bad stitching, but the stitching is actually good and the mechanical properties are sound. From a datasheet point of view, if the part behaves in the same way as a single-laser part (in terms of tensile and fatigue properties) then you have a well-stitched part.

Q: And how about bad stitching?
Whatever is different from a single-laser exposure can be interpreted as bad stitching. For example, if you have visible contour ends sticking out from the surface, any surface discontinuities, sub-surface porosity, or even bulk porosity—in extreme cases that cannot be attributed to the single-laser parameter—then you have bad stitching. In areas where there is a deviation from a smooth surface, the surface discontinuities can also cause cracks to form, depending on the load applied to it, which is critical to fatigue-relevant parts.

Q: Why is validation important when it comes to stitching?
There are two types of validation that we do at GE Additive, validation of the machine and validation of the process.

We set up design of experiments (DOEs) for the many possible scenarios involving stitched and non-stitched parts at different build plate locations. This way, we have all the possible inputs that can influence the stitch part in the DOE. This is done over several builds and several materials and uses coupons and bars and subsections of actual parts to test the material properties.

We also create parts using certain misalignments to see how different misalignments affect the part quality. The DOE setups also allow us to see what the thresholds are for each part without using countermeasures so that we get the mechanical properties that are statistically the same as a single laser. This then allows us to understand what the machine misalignment capability is so that we can ensure that the customer gets a safely stitched part.

The second type of validation is for large parts, where coupons and bar results are not enough. In these scenarios, large parts are printed several times on the M Line with different configurations and settings, followed by heat-treated and non-heat-treated analyses. This allows us to see if the stitched regions come out in a satisfactory manner on a big-part level in terms of porosity and surface finish. This is typically a big endeavor and much harder than validating at the coupon/bar level.

Q: Should additive users be concerned about stitching?

It's a perfectly valid response to be concerned, because there's a lot that can go wrong if the right protocols are not in place. However, if your machine manufacturer can provide you with data and results about the mechanical properties of the part, including machine-to-machine and build-to-build variations, and show that there's no difference between a single-laser-exposed part and a multi-laser-exposed part, then there should be no issues, as long as the machine is calibrated within the acceptable threshold levels.

In general, customers should pay attention to the smaller features in their parts. Stitching gets more and more complicated the smaller the features and the thinner the walls. For example, on a heat exchanger, multi-exposure on very small areas, including misalignments, can lead to critical porosity.

Overall Outlook on Stitching

While stitching can be a hard process to do well, with the right care, protocols, and calibration efforts, the stitching is not as scary as many people think. Additive users do need to make sure that their machines are running optimally and are calibrated every 3-6 months, and by employing software countermeasures, can have a larger margin of error when it comes to the alignment of the optical systems.

Working directly with the machine manufacturer to ensure that all systems are running as intended, and before starting printing, additive users should ensure they have been presented with all the correct mechanical data that shows the stitched part has the same performance as a non-stitched part. With all this in place, there should be no worries regarding the mechanical properties of your printed parts.

If you'd like to find out more about how you can work with GE Additive's engineers to ensure that you get the right stitching advice and data that fits your needs, get in touch.