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Get the facts on material performance

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Material performance is a broad term that means a lot of things to a lot of different people. No matter how it is interpreted, we work with our customers (additive technology end users) to ensure that they are getting the right level of material performance for their intended part and application—regardless of whether that is porosity, a high surface finish, or specific mechanical properties.

The mechanical and technological needs of a part differ from application to application. So, a customized and tailored approach to the material performance of a part is needed for every customer at GE Additive. We caught up with Johannes Stroessner, Principal Engineer & Sub Section Manager - Process & Application Development, GE Additive, to discuss what material performance means to different users.

Q: What do our customers understand by the term 'material performance'?
I hate to use the standard engineer response, but it really does depend, as material performance is a broad and diverse term. Each customer has its own application in mind and a part performance that they want to achieve. We have more advanced additive customers, such as GE Aviation, which has established design curves with very clear and measurable requirements with a strong focus on the mechanical properties, so that they can operate their parts in a safe manner.

We have other customers that are using additive for applications for which they are less concerned about mechanical properties and more focused on the productivity and availability of the printing process. Others might be primarily concerned about surface finish – they just don't want to spend a long time post-processing the part to get a shiny surface.

So, it's dependent on the customer. To develop a parameter with the suitable material properties, it's important to listen to the needs of each customer. Some customers still need guidance on what they want and need—they have an idea or application in mind, but they can't give a specific property level that they want to achieve. It's our job to translate their needs and what they understand as material performance into requirements for the printing process and actual values that we can measure.

Q: Why does GE Additive care about the performance of materials?
Because it's the material performance that often drives the decisions of the customer. We have some customers who don't ask for specifics about the machine, such as how the optics and gas flow are set up, and they would rather ask 'Can I process and manufacture my part successfully?' It's not typical that a competitive assessment of

the achievable material properties is a major factor in the decision-making process for a machine purchase.

In these cases, we need to ensure that we have the ability to understand and show customers what we are able to achieve and can offer to the market. Therefore, it is important that we run parameter development programs and extensive material characterization programs.

By doing this, we also learn about the gaps and needs in our systems, and this information can be fed back to the hardware development team. This is essentially the driver for how we develop the machine hardware, as well as understand where we can continuously improve the hardware to obtain an improved material outcome.

Q: There's an intersection between stability and material performance. Can you go into a bit more detail about that?

When you start to move from successfully printing a prototype part one time to the point where you are scaling production and need to process the same part hundreds of times, stability and robustness become very important factors.

Stability can be thought of in many ways. On one hand, you have the machine side of things with the gas flow, optics, and components that come with certain manufacturing variations and influence the part quality in the end. On the other hand, you have the platform, where factors like the gas flow, recoating direction or the position of the scanners are potential sources for variation across the platform. You need to ensure that the parameters you are operating the machine with are robust enough to handle those factors so that we can guarantee the same level of performance across the whole platform.

If we can guarantee performance for one machine, the next step is to ensure the quality level for multiple machines and multiple builds. This is when we need to be able to exactly understand how hardware component variation is influencing material performance and how to deal with it, as well as other influencing factors, so that the performance in the end is in line with customer expectations and requirements. We have multiple approaches to ensure that the parameter sets created during the development process are able to withstand those variations.

Q: What approaches for parameter development do we have in place?

For developing a successful and robust parameter set, the first thing we need to do is understand the requirements of the customer. This involves translating those general requirements into actual values you can measure. We then start our development process by performing design of experiments (DOE) while considering the variation of the machine and other influencing factors.

GE Additive has extensive knowledge about the influencing factors and how much they could affect the print, so during the development process, we not only develop the parameters to a certain nominal point, but we also go beyond to understand the wider process windows. By doing this, we understand at which calibration point or parameter adjustment we will see a significant drop in material performance.

At the end of a parameter development, we do confirmation builds during which we check the performance of the parameter one more time. In those tests, we check to see if the properties of the parts are still good across the whole platform if we misalign the parameter set or machine within certain ranges. If this is the case, then we release the parameter set and make it officially available for that machine. We have recently added the results of platform stability builds (one part of the confirmation checks) to our data sheets, so anyone can see the amount of expected variation across the platform of our machines.

Q: How do you deal with data in respect to parameter development? How important is that data?
Data is important, as it guides us to make a decision to ascertain whether a parameter set is robust enough.

You also need to test in a way that the results are significant and that you can easily tell from the data if your assumptions are correct or not. Then there is the variation to account for. For example, powder is a source of variation, where the powder size distribution (PSD) and the chemical composition of the powder slightly differs. This will affect some of the properties of the part even though this variation does not affect the machine in any way and the parameters remain unchanged.

By capturing the data in a strategic way, and by understanding how different factors drive variation, we can understand what kind of non-machine variation parts can be expected and how we can accommodate that variation during the parameter development.

Q: Could you talk about variation in the context of stitching?
Stitching is important. Stitching is when multiple lasers come together and expose one part. So, when you have a region in the part where both lasers come together, you get stitching. From a dimensional, surface, and mechanical property perspective, it's important that the lasers work together in an accurate manner. The machine hardware can help to guarantee seamless stitching by making sure that the optical systems are well aligned.

However, as I mentioned, there is always some variation within a machine. So, you also need to understand the material answer to a potential misalignment—that is, what happens to the mechanical properties or the porosity of the part when there's a misalignment. If you can understand both sides—the material answer to a misalignment and what the machine can deliver—then you bring both pieces together to achieve a good stitching outcome that fulfills the customer's requirements.

There are also some mitigation techniques that can be employed during parameter development to reduce the effects of misalignment and achieve a better part performance. For example, measures can be taken to achieve a better surface quality in the stitched zone. Of course, outputs that we generate on the material side also feed into the solutions on the hardware and software side of things.

Q: What are some of the typical performance criteria and/or properties that you measure?
The properties that we typically measure and analyze for are porosity, mechanical properties, tensile, elevated temperature tensile properties, and surface quality. For enhanced applications, we also look at dynamic mechanical properties, such as fatigue testing. We also characterize the microstructure, analyzing the morphology of the defects, grain size evolution and the isotropic behavior of the material.

Q: What's the basic level of material characterization that you perform at the end of the parameter development?
Whenever we release a parameter set, we have static mechanical property data across the whole platform, as well as the surface roughness properties (upside, downside, vertical wall, various geometric features), the porosity of the part and etched micrographs of the part's microstructure. This data is not only on the nominal parameter set, but the whole parameter window. This is the standard and is what every customer can expect from a GE Additive parameter set.

Q: Can you describe a more complex scenario when it comes to material performance?
The more complex a requirement set becomes, the more chance you have of getting conflicting requirements. For example, there is no parameter set that will deliver a super-high productivity and the best material performance. So, it is important to stay in close contact with the customer and include them in the development process so that they are made aware of any potential trade-offs that they may have to make.

So long as the trade-offs are based on data and that there is no other viable solution from an engineering perspective, then we can work together with the customer to find the optimum parameter combination and the best trade-off which still fulfills their requirements.

Our work together with GE Aviation on their applications is increasingly complex. To manage that complexity, GE Additive developers both in Lichtenfels and in the US work alongside developers from GE Aviation. We review the results together at least once a week, make the decisions together and decide on the best outcome.

Material properties are one piece of the puzzle. You are working with complex parts, and we do not necessarily know which of the features within the parts are the most important ones. So, it's beneficial to have customer input so we can determine on which coupons and segments we should print on a small level before printing on a larger scale and ensure we are headed in the right direction.

Overall Outlook
Material performance means different things to different people, and there is no one set answer for what material performance is. For one additive user, it might be a high surface finish; for another, it might be a high fatigue strength. So, we cannot underestimate the importance of listening to customers to find out what material requirements they need for their intended application.

Developers and users should always understand material performance from a broader lens to ensure the parts you are printing are able to deliver material performance in a robust and stable manner.

Therefore, the machine and material performance shouldn't be differentiated as they link together. Understanding this link during process development is key to understanding how you can improve material performance by adjusting the machine by changing the hardware.

If you'd like to know more about material performance or find out how one of material science experts can help to find the best solutions for your application, get in touch.