3D printing polymer parts with digital continuity

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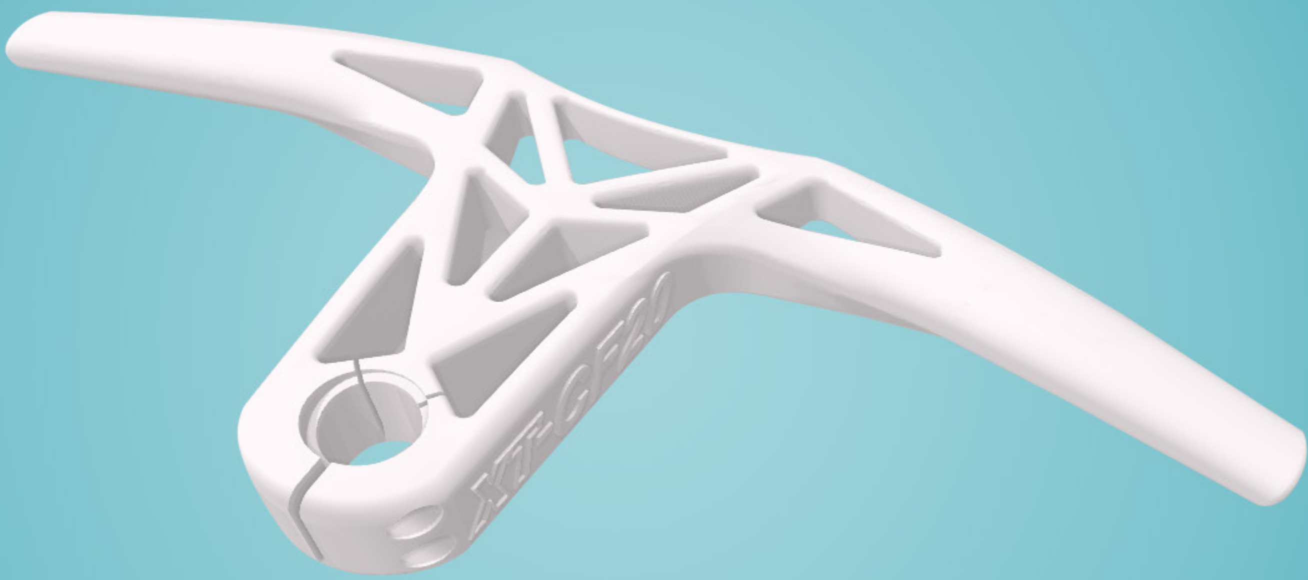
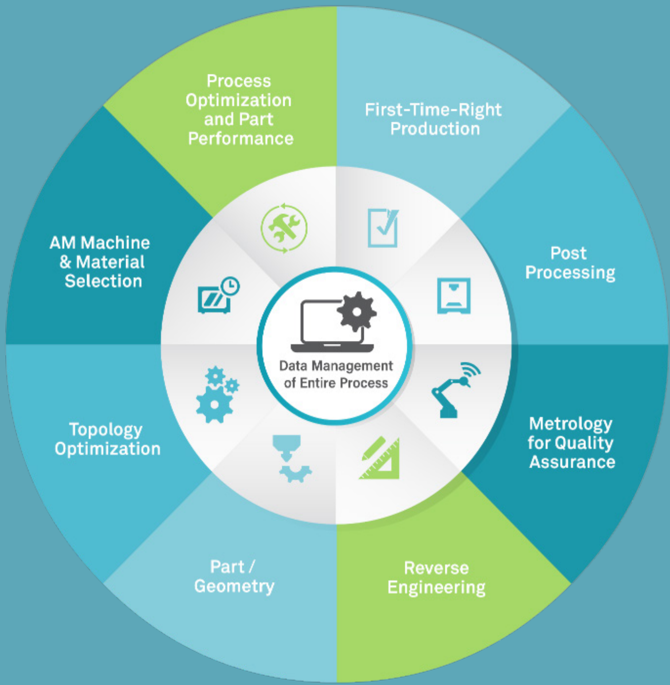


Material development processes usually involve multiple steps, and some of these have simulation equivalents that have high predictability as a result. When it comes to polymer additive manufacturing, a product like Digimat provides digital twins of printing materials and for printers who 3D print to enable high fidelity predictions of as-manufactured shapes and their performance. Today, Hexagon's mix of production software, design & engineering simulation software and metrology scanners provides a unique set of technologies for end-to-end 3D printing when couple with an open ecosystem towards other software tools and an array of 3D printers available on the market. It enables the user to plan, optimize, validate and replicate high quality additively manufactured parts robustly, accurately, and very fast.



This Additive Manufacturing solution can be represented by the 'wheel' graphic above and is a combination of part geometry manipulation, topology optimization, Additive Manufacturing machine and material selection, process optimization by virtual simulation, first-time-right part production, metrology for quality assurance of the as-manufactured part, and metrology for reverse engineering. All these steps are backed up by the robust and efficient data management system for the entire process, MaterialCenter. What we call a 'Digital Continuity' approach to integrated computational materials engineering will combine both virtual and real capabilities, using directly inline inspection of parts to feed the numerical chain for design verification. Also, it is possible to verify the discrepancy between the as-programmed configuration with the real as-manufactured configuration. Digital Continuity therefore supports the development of next generation of manufacturing processes; what is called 'Industry 4.0'.

Let's describe a couple of examples of Digital Continuity, first focusing on 3D printer machine material selection as well as a process optimization simulation example. If we look at a typical 3D printed polymer bracket (Figure 1) we might want to ask a question like 'which printing orientation should we choose to achieve the best process and part performance knowing that the material has been fixed, being polyamide reinforced with carbon fibers?' And we might like to choose between two orientation possibilities: one with the bracket oriented in an upright manner and another where the bracket is lying flat on the build plate. What we clearly want to achieve is a multivariable design optimization smart decision that also combines different factors such as print time, the part's weight, its dimension tolerance, and its stiffness and strength.

To define the dimensional tolerances for this bracket, we would first need to run a process simulation of the part for the two different printing conditions we have selected. The conclusion from that process simulation after we carried it out was that excessive warpage occurred by default and warpage compensation is therefore required. Thanks to warpage compensation simulations we were able to validate both printing strategies to meet the dimensional tolerances of our problem. We used structural analysis in Digimat AM to assess both the stiffness and strength performance of the two printed parts. This was done by running a coupled finite element analysis (Figure 2) accounting for the local manufacturing history and the local microstructure of the material, including fiber orientation distribution dictated by the deposition strategy we employed.

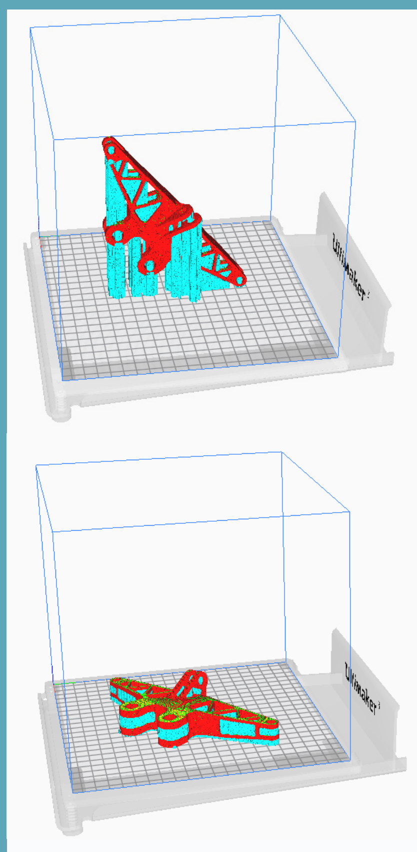


Figure 1: Multivariable analysis of a 3D Printed Polymer Bracket with upright and flat printing orientations

Figure 2: Virtual performance comparison

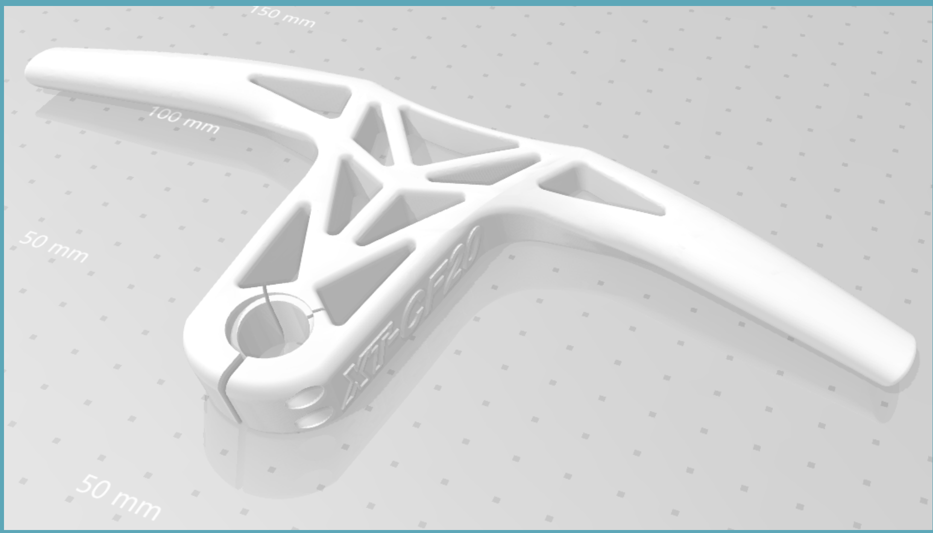


Figure 3: 3D printed polymer bike handle

The Digimat AM simulation prediction for the bracket provided a very strong indication of which one was the best orientation to print. Indeed, when we virtually test parts that are 3D printed we can choose the oriented approach. In this example we obtained a stiffness which was twice as small for the upright printing orientation than for the flat one, while the strength for the upright orientation was approximately one-quarter of the strength for flat part printing. Hence, through this digital simulation process we were able to identify that the flat orientation combined process quality, part performance as well as optimal print time and was best.

A second 3D printer example of our Digital Continuity vision is shown in Figure 3 by way of a polymer bike handle. It is created by the Automated Fiber Placement manufacturing process. In this process, tows of unidirectional composites are deposed onto the mould to form at the end of the composite layup. However, to accommodate the composite layer onto the surface it is necessary to cut the strip at several locations that then leads to the appearance of gaps between the tows and therefore a need to modify the fiber's orientation. For design purposes it is important to really use the fiber orientation as-manufactured and to take into account the presence of defects like the gaps. To do so, we can rely on two approaches. The first one consists in retrieving information coming from the process manufacturing simulation software and to use such information in a numerical chain combining material engineering with Digimat and its structural analysis. A second approach would consist of using directly information about the material coming from inline inspection relying on scanning inspection systems like the Apodius Absolute Arm scanner (Figure 4). Digital Continuity is part of what we call our '10x ICME Solution at Hexagon which includes an extensive suite of simulation equivalents for material development, material characterization, manufacturing simulation and final part performance. Ultimately a digital twin of the material manufacturing process is obtained and improves predictability leading to companies seeing 10x productivity gains, time-to-market, and cost savings through manufacturing right-first-time.

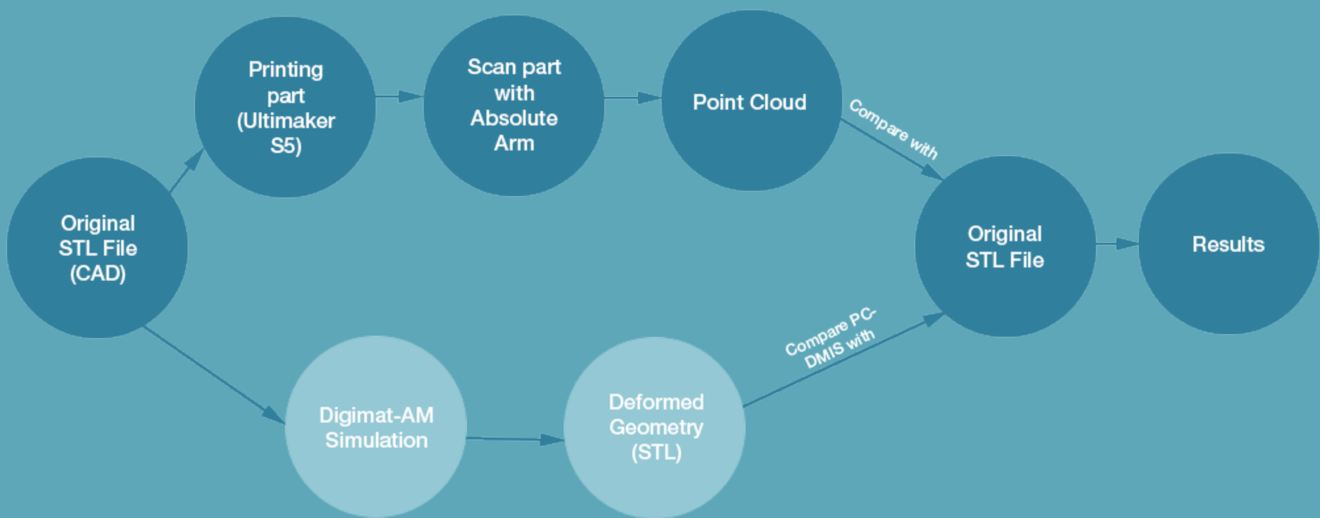


Figure 4: Digital continuity chain for the 3D printed bike handle case