

# Optimize the Product Part, Not Just the Geometry - A Real World End2End Additive Manufacturing Solution

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**W**ith the continuing rapid adoption and development of additive manufacturing techniques and technologies in multiple industries led by aerospace, defense, medical and automotive, many benefits can be obtained in companies. This includes the huge potential for lightweighting, small production runs with less material waste, significant energy cost savings, and the possibility to produce functional, high performance parts that simply can't be subtractively manufactured, cast or formed. One of the challenges is a full automation and to minimize the physical try-outs. This can only be achieved with a full digital transformation and a fully connected workflow.

With the acquisition of MSC Software in 2017, and its manufacturing oriented and material focused business units of Simufact and e-Xstream in particular; Hexagon's Manufacturing Intelligence Division now has in its portfolio a unique combination of tools including cutting edge CAD/CAM production software plus existing market leading metrology solutions. The smart factory solution Xalt from Hexagon is offering the needed framework for the connecting of all data (from real and virtual sources) to enable a fully connected workflow and transparency of the process.



**Figure 1: End2End Workflow for Virtual Simulation, Printing and Scanning in Additive Manufacturing**



Figure 2: Concept of a folding bicycle with 3d printed Metal and Polymer parts

These technologies within Hexagon allows the development of a compelling solution for the challenges of the additive manufacturing industry where unit costs can be high and errors can be costly. It is important to not just optimize the 3D CAD geometry during 3D printing, but also, to optimize the end product part. There is a need for real world solutions that are fast, accurate and robust than alternative PLM and CAD-based methods. In effect, with this combination of technologies I believe it is now possible to plan, optimize, validate and replicate high quality additively manufactured

metal or polymer parts in a straightforward way so that they are 'First Time Right' printed. Let us unwrap that statement a bit by way of first outlining a typical End2End Additive Manufacturing workflow (see Figure 1). And secondly, using an example for a new innovative lightweight folding bicycle concept (see Figure 2). We choose two typical parts from the bike, to demonstrate the principles for the available solutions for metals and polymer. The first is a handlebar upper fork as a 3D printed metallic part and the second one a bike saddle as a polymer part.

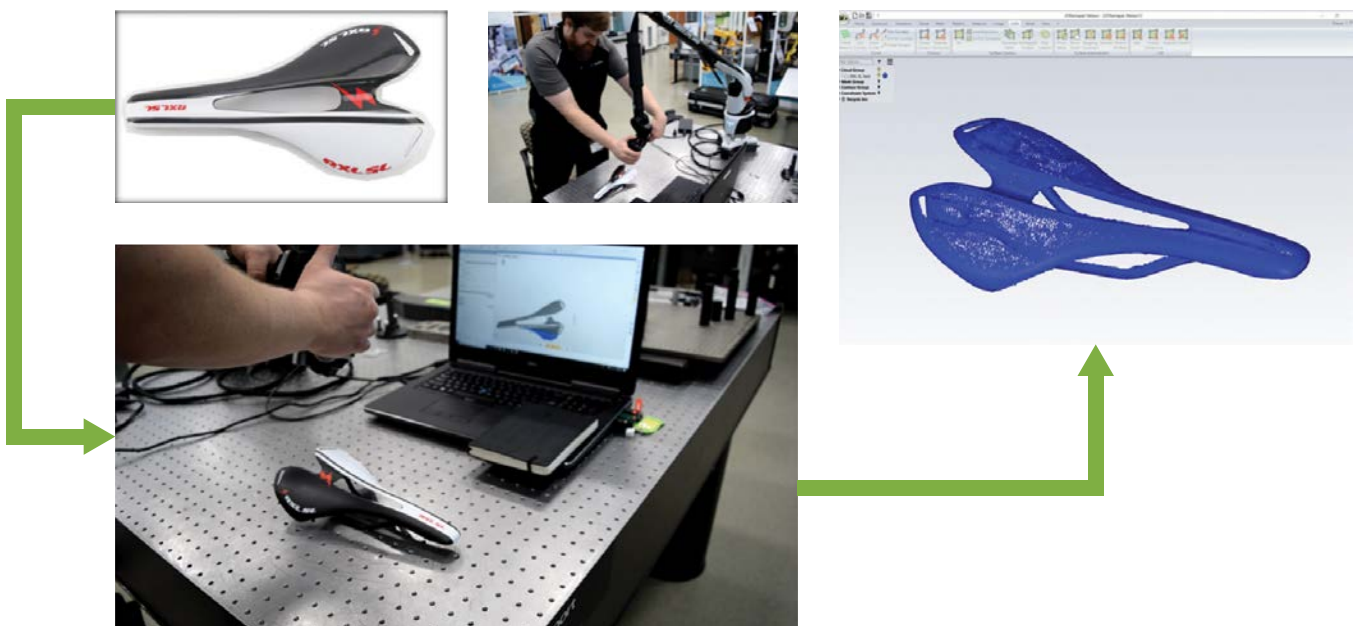
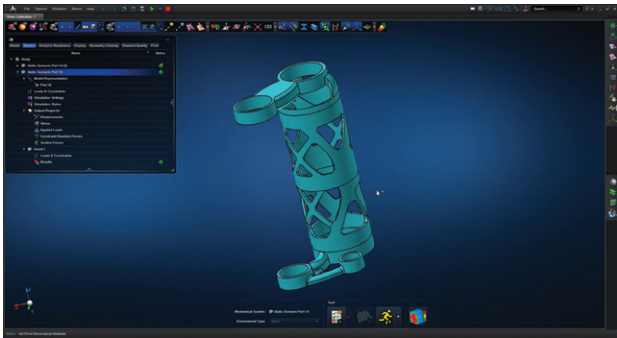


Figure 3: Process of Reverse Engineering the Arena Seat Saddle using a 3D Scanner



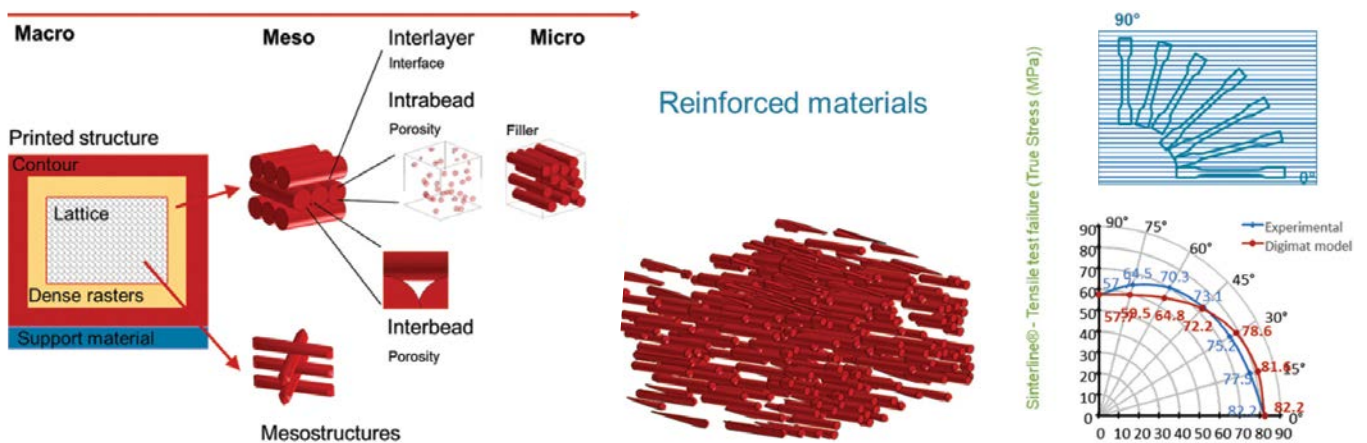
**Figure 4: MSC Apex topology optimization of the folding bike fork geometry**

The wheel in figure 1 shows the overall workflow and data flow. You can start in any of the segments depending on the requirements and parts you want to produce. The geometry for the part, which we want to print, can come from different

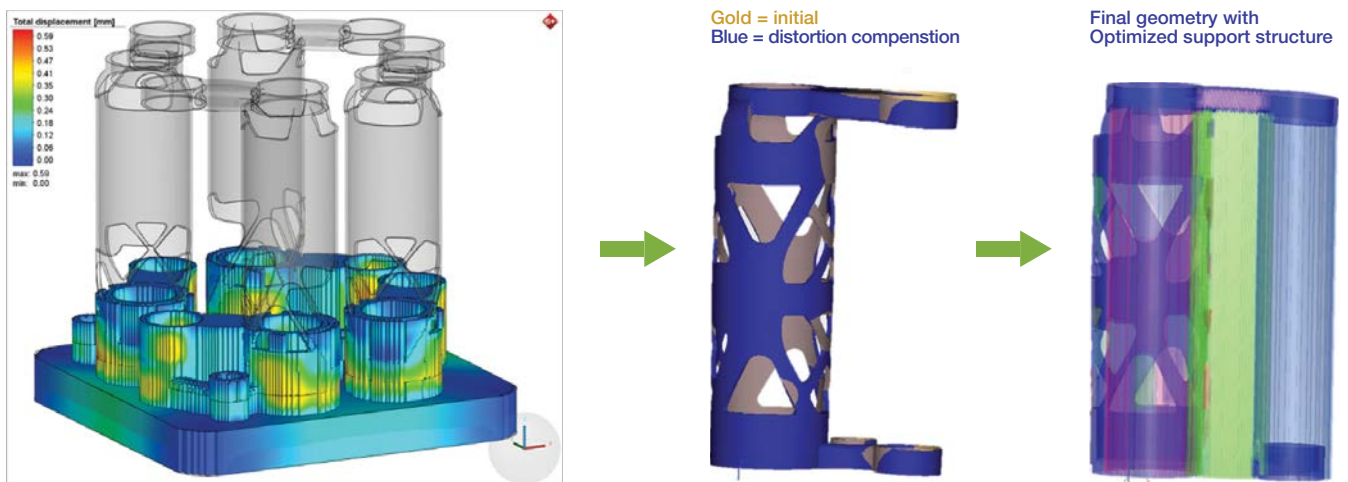
sources. As an example for a 'reverse engineered' part, we used the bike saddle. The geometry was created out of a 3D scanned point cloud, see Figure 1: 5 o'clock (Figure 3), where we used a Hexagon Absolute Arm 7-Axis machine.

For the handlebar upper fork, we carried out a topology optimization of the part, Figure 1: 7 to 8 o'clock, in a suitable CAD-centric tool like MSC Apex (Figure 4 shows the fork part). Used in early design, MSC Apex allows users to obtain geometries that will withstand the loads on the component and minimize its weight (by as much as 70%). Topology optimization therefore can be used to redesign existing components and account for manufacturing constraints early on. After this optimization step, the user needs to be able to evaluate the strength and stress of the optimized design by predicting its distorted geometry on full loading to see if it fits within allowable tolerances.

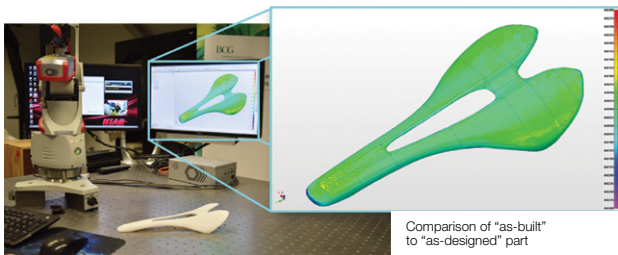
Once a suitable geometry has been designed, like all computer-aided engineer simulation predictions, the build process need to be qualified, critical areas to be identified and at the end the whole



**Figure 5: Schematic representation of polymeric materials in MaterialsCenter**



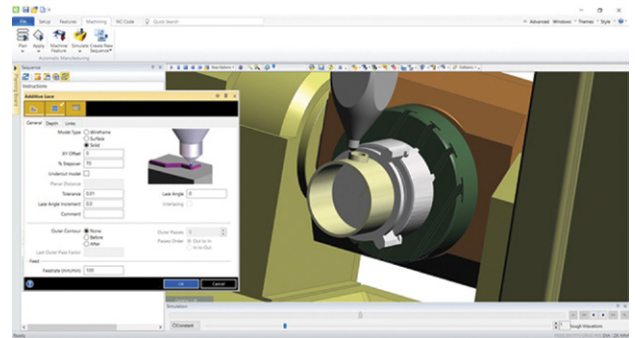
**Figure 6: Comparison of simulated and optimized 3D printed metal Fork part in Simufact Additive**



**Figure 7: Comparison of the final 'as-built' 3D printed polymer seat part to the 'as-designed' part in Digimat Additive**

process chain needs to be optimized, so that we will get the right shape with the required part performance. The final part performance is the outcome of the used process and print parameter. The data can be taken for all materials from an open and flexible material data management tool like MaterialCenter from MSC Software (Figure 5). This solution was adjusted dedicated to AM, to be able to handle all experimental data, to calculate the needed parameter out of it for the material models for the simulation and finally, also to control all material properties during the production process. The final material properties need to be documented and stored for sensitive parts in AM. MaterialCenter is the perfect solution to be used besides the production and for the virtual manufacturing simulation as a digital twin.

But let us go back to the manufacturing simulation (Figure 1: 11 o'clock). MSC Software offers best in class technologies with Simufact for metals (Figure 6) and Digimat for polymers (Figure 7). The simulation will predict the distortion and behavior of the parts (fork and saddle) during the whole process chain and will detect critical areas or possible problems. This enables the user to optimize the whole process steps and minimize the risk for manufacturing problems. The



**Figure 9: Hexagon EdgeCAM's knowledge of machine control in Additive DED machines**

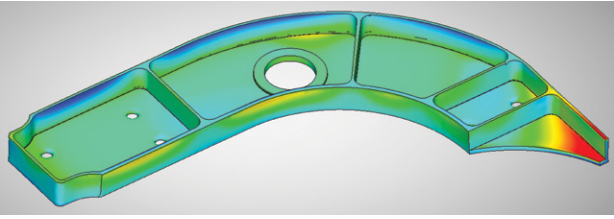
whole process will become more transparent and the process can be made more robust to ensure that all errors are eliminated before the designs are committed to in the printers.

In the shown folding bike scenario, we worked with a Hexagon partner organization, NIAR, at Wichita State University in America to use their 3D printers to additively manufacture both the fork and the saddle (Figure 8). This part of the process is represented by the segment in Figure 1 at 1 o'clock where you go through the 3D printing process based on the optimized designs from the CAE software predictions at Figure 1: 11 o'clock. We want to thank NIAR for their collaboration in this project.

30% of the costs are incurred directly through the post-processing step for machining of the printed part. The used orientation of the part during the process and therefore the needed support structures etc. are directly influencing the effort for the machining stage. So there is a need also to take this manufacturing step into account to be able to optimize the whole process chain with all the main influencing steps. It also has an impact on the predefined design and can be used to minimize the total costs. That is why MSC is developing an



**Figure 8: NIAR facilities for 3D printing and the machines used in the bike saddle and fork printing**



**Figure 10: Distortion of a DED additive manufactured part after the machining process**



**Figure 11: Final inspection of the 3D printed polymer seat part Hexagon Absolute Arm**

End2End solution with a closed feedback loop. It further allows supporting better hybrid machines in the future.

Hexagon MI has dedicated production software tools for machining operation, which are simulating the toolpath and machine behavior that will be connected with the manufacturing simulation to predict and optimize the tool path and machining and printing strategy. This can be used also for direct energy deposition processes (DED) based on blown powder or wire-feed for large structures or repaired parts (figure 9). Figure 10 shows the final distortion of an Airframe after a DED process and machining simulation. This solution from Simufact is still under development and should demonstrate the ongoing activities from MSC in the field of Additive manufacturing processes and how we take advantage out of being part of Hexagon for the most benefit for the customer, to connect production software and manufacturing simulation.

Finally, we validate all simulation results with the real measured data (Figure 1: 4 o'clock), by using a Hexagon Absolute arm to scan the 3d printed plastic seat by acquiring a point cloud using the physical dimensions of the 'as-built' part to inspect the final part for quality assurance. The simulation results were proofed and it was found to be very close to what was required in the specification, as indeed was the metal handlebar fork we

had NIAR print. The simulation results stand for quality and the use of the software tools for productivity.

## Summary and Conclusions

Hexagon's virtual predictive design & engineering simulation software from MSC Software, production simulation software, and 3D metrology measurement workflow for additive manufacturing captures the entire process chain (Figure 1) through a printed part's final 'as-built' performance. Virtual printing stress analysis simulation (either by Simufact for metals or Digimat for polymers) allows users to optimize the 3D print process via these innovative simulation tools, thus saving time and material cost. We have illustrated this by way of two components from an innovative folding bike design.

Good 3D CAD geometry topology optimization (under development via MSC Apex, our modern CAE preprocessing tool) allows for fast identification of the part geometry design parameters in order to minimize material cost and printer time. It will be directly linked to the manufacturing simulation and will take the manufacturing constrains into account. This enables the designer to optimize a good printable part with the right part performance for the loads.

The data management of all important material data, from test through simulation up to the production and process parameter, requires a good data management solution. MSC has developed a solution dedicated for AM based on MaterialCenter. Support of good material properties ensures the most accurate simulations predictions for either metals or polymers. Finally, after printing the part with your 3D printer of choice, Hexagon metrology's state-of-the-art scanners can verify the accuracy of the simulations and compare the 'as-built' part to the 'as-designed' part. This allows for genuine 'First Time Right' 3D printing. Typically, with this workflow, we find that we can get useful engineering simulation results for additive manufacturing in minutes and hours versus hours and days for alternatives.

The virtual and real world with all different sources can be connected via Xalt and linked to PLM systems. With Hexagon technology the users will be able to make the design and development smarter and at the end have a smart virtual and real factory.

**MSC Software and Hexagon's Unique Additive Manufacturing Solutions:**  
[www.mscsoftware.com/additive](http://www.mscsoftware.com/additive)