Bridging the Gap Between

Design and Additive Manufacturing

Using Smart Generative Design

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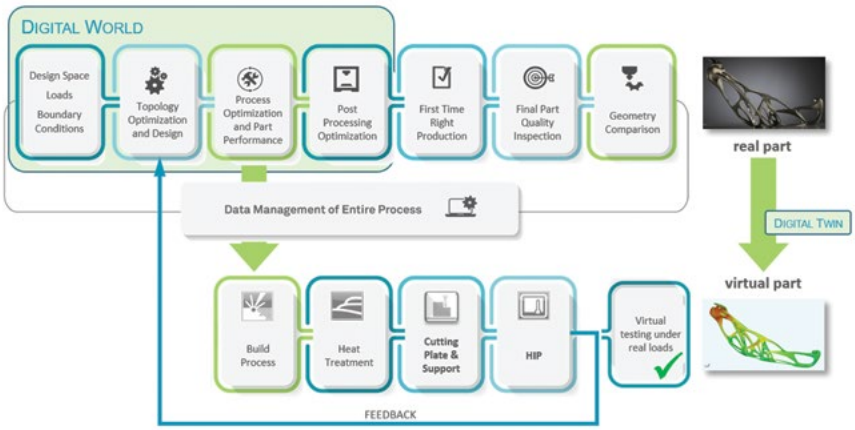
For MSC Software and Hexagon, Generative Design is an initiative to provide a tool that will help customers design concepts unimaginable by the human mind.

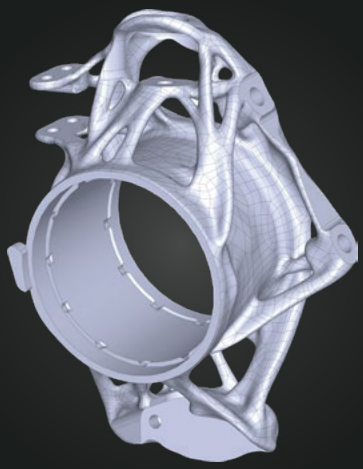
With the release of MSC Apex Generative Design, MSC Software is now offering an entire digital solution from the design to the final validated part for all materials. Connecting design solutions like MSC Apex Generative Design to virtual manufacturing simulation with Digimat AM or Simufact Additive, the design can account for the engineering and production phase challenges earlier in the product development phase. As a digital twin, the virtual manufacturing simulation is used to identify the best printing process and to optimize the orientation of the part and the build process. Furthermore, the outcome of the additive manufacturing process chain can be used for the validation of the "real" geometry, while accounting for the residual stress distribution and the local deformation under real load conditions using MSC Software's design validation solutions such as MSC Nastran or Marc. The end-to-end process enables engineers to make sure their optimized designs are validated for manufacturability and performance.



What is Generative Design?

Simply stated, Generative Design is a process of automatically generating several design concepts that satisfy a set of user defined objectives, criteria, and constraints. Generative Design can be accomplished in many ways depending on what criteria and constraints have been defined by the user. For example, if a user defines a set of structural loads and boundary conditions that a part must withstand as criteria, an upper stress limit as a constraint, and an objective of minimizing mass, a method known as Topology Optimization (which many of our MSC Nastran users are very familiar with) can be used to generate a number of design concepts that satisfy the given criteria and constraints. However, Generative Design is more than just Topology Optimization. For instance, a user may want to know what the best way is to package a number of electronic components in a given space in order to minimize the gap between all the components. Generative Design can help answer that question. For MSC Software and Hexagon, Generative Design is an initiative to provide a tool to our design customers that will truly act as a companion and help them think of design concepts that are unimaginable by human mind.

Why Do We Need Generative Design?



The first release of MSC Apex Generative Design has been released to assist design engineers create organic topologies that can be manufactured using 3D printing, i.e. Laser Powder Bed Additive Manufacturing. Technologies such as Topology Optimization are being reinvigorated thanks to advancements in Additive Manufacturing. It is widely accepted that Additive Manufacturing has the ability to manufacture virtually any topology. As a result, the industry has seen a rise in the number of tools that allow creation of organic topologies via concepts such as Topology Optimization and Generative Design. However, if you have ever tried to 3D print any "organic" topology that resulted from the Topology Optimization algorithm, you have probably realized that AM is not very forgiving, and an unrevised Topology Optimization result often is far from feasible. Despite its unique ability to manufacture virtually any topology, AM still has many limitations today. Issues such as shrink lines, cracking, overheated zones, etc. have kept AM from replacing other manufacturing methods. These issues were not as pervasive when 3D printing was only used for prototyping. However, they become prevalent when using AM for production parts, especially primary or secondary structural parts for Aerospace or Automotive industry. Today, cost of manufacturing and time of printing are seen as two major constraints in wide adoption of AM for mass production. Therefore, there is a need to account and optimize for the total manufacturing costs and print time while designing parts for AM. With MSC Apex Generative Design, we are focusing not only on optimizing the parts for AM, but also optimizing the process for AM. We believe that it is only after we bridge the gap between design and manufacturing that we can see AM become a sustainable manufacturing method.

Bridging The Gap

MSC Apex Generative Design is being developed as a first-of-its-breed tool to bridge the gap between design and manufacturing. Our goal is to automate the process of Generative Design with user intervention only required for defining the objective, criteria, and constraints for design space exploration. MSC Apex Generative Design will then account for how the part fits within the overall assembly, how it redirects loads to other parts of the assembly as its stiffness changes, and most importantly MSC Apex Generative Design accounts for manufacturability – all automatically while generating several design candidates that all meet the user's defined expectations. Many Generative Design tools in the market today allow users to minimize the mass subject to a stress constraint. The tool then solves a mathematical optimization problem and produces one or more design candidates. Although these candidates often are more ideas for a part and visualizations of how the forces flow through the design are. A proper Generative Design tool needs to produce directly printable designs that can be used without any need for manual rework of geometry defects. This is what MSC Apex Generative Design will deliver.

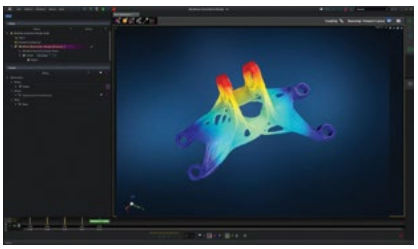


Figure 2: **Topology Optimization of a GE Engine Bracket using MSC Apex Generative Design**

Each optimization always leads to a geometrical and mechanical correct design that can be used for manufacturing. In addition to the geometric side, the user must also understand the cost and feasibility of using AM for this design candidate. With MSC Apex Generative Design, our goal is to allow users to specify manufacturing related constraints. For example, if the goal is to minimize the cost of 3D printing, then MSC Apex Generative Design will automatically check each design candidate for: (a) amount of material required for the part, (b) volume of support structure required for support and heat dissipation in the AM machine, (c) cost of removal of support structures and machining for desired surface roughness, (d) costs related to maximizing the number of parts printed at one time on a build plate, etc. These checks are performed in the background using MSC's Simufact Additive technology for metal parts and Digimat AM technology for polymers. At the end of the optimization routine, MSC Apex Generative Design selects the candidates that meet the specified criteria and summarizes them. The design engineer can then export the selected design(s) in CAD format and perform further checks, for example, for buckling, fatigue, and nonlinear for part performance or decide for one design based on additional reasons such as of dirt problems or just aesthetic ones. The design engineer may also choose to send the part to a manufacturing engineer to perform further checks on manufacturability via Simufact Additive and/or Digimat AM. Users will be able to perform any geometry modifications needed using the geometry editing tools in MSC Apex. Eventually, MSC Apex Generative Design is able to perform these checks during the optimization process automatically as well.

Speed Is Crucial

In order to evaluate several design candidates in a time effective manner, it is necessary to have a finite element solver and an optimization engine that can take advantage of the latest computing technologies for extremely fast performance. With MSC Apex Generative Design, we have done exactly that. We have completely rewritten the FE solver and the optimization engine to scale on multiple GPUs and CPUs. The ability to explore design space in a time efficient

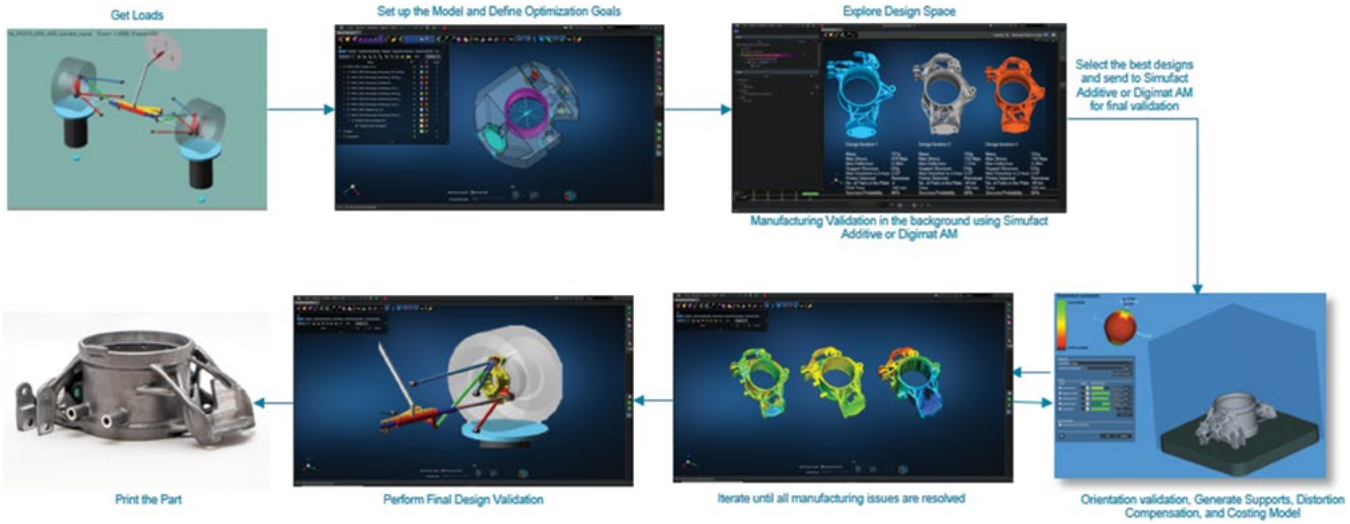


Figure 3: **Design for Additive Manufacturing using MSC Apex Generative Design**

manner ensures that the design process is not a bottleneck and thus allows our users to make decisions solely based on design criteria. Only a complete examination of the design space with a variety of results, and in a short time, leads to the best results.

Demonstrating The Potential

To bring evidence on the potential of MSC Apex Generative Design and to show its usability, a wheel carrier of a formula student team is considered to demonstrate a use case. Due to its very complex load cases and a high demand on lightweight design, it is the perfect fit for demonstration. Furthermore, there is a lot of experience in optimizing this part, as this race series officially is an engineering competition that requires to develop a new race car each year. Other MSC tools such as Adams and MSC Nastran have been used for this part in the past for optimization.

As shown in Figure 3, the development process starts with retrieving the loads by a multi body simulation based on Adams Car. Hereby, the overall suspension is engineered, including all coordinates for the connection points, as well as the acting forces. This information is used to set up the optimization model and define its goals. Therefore, a "design space" as big as possible is added (shown as translucent material). In this case the overall inner space of the rim minus the installation space for wishbones and braking system is selected. Running the optimization, this material in the design space is reduced as much as possible while keeping into account the boundary conditions, constraints and optimization goal. Thus, several design candidates are produced and directly verified in the background using Simufact Additive for metals or Digimat AM for plastic products. While selecting the right candidate and iterating the manufacturing simulation, the perfect design in terms of manufacturability, weight and costs is selected. As a last step in the virtual world, this design finally gets a last validation with MSC Nastran for FE qualification and back again in Adams to ensure the correct stiffness and behavior in the overall assembly. Thus, an optimal design was found that was printed and successfully used in this year's formula student season.

Summary and Conclusions

MSC Software's MSC Apex Generative Design is bridging the gap between design and additive manufacturing. Additive Manufacturing has come a long way since its inception and is changing the manufacturing landscape. In order to realize the full potential and benefits of AM, users need to be able to produce designs that are specifically validated for AM. With MSC Apex Generative Design, we are developing technologies that validate manufacturability in the Generative Design process. As such, the optimization engine only produces geometry candidates that have been validated for AM.

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. Time and cost are two of the major constraints in wide adoption of AM today. Typically, with MSC Software's Generative Design solution we find that we can cut the time and cost of simulations by x10. Furthermore, most importantly, with our bridge to manufacturing, we find that we can get closer to "First Time Right" 3D printing. MSC Apex Generative Design technology is here to make the design and development for AM smarter and more sustainable.

Read an Overview in our Previous Issue for More Information on Hexagon and MSC's End-to-End Solution: www.mscsoftware.com/Engineering-Reality-Summer-2019