FUNCTIONAL GENERATIVE DESIGN

Streamline the creation of optimal and manufacturable designs through topology optimization

The design for a new concept is defined by the requirements of the application, as well as the constraints of the manufacturing method. Both factors need to be taken into account when creating an optimal design. It is essential that a component be able to meet the specifications, but it also needs to be able to be produced quickly, cheaply and reliably enough to meet demand. Functional generative design offers a way to balance both of these requirements simultaneously to find an optimal design that is ready to be manufactured.

Function-driven generative design accelerates the development process by optimizing the material layout within the initial design space, targeting maximum performance for given loading conditions. The workflow can cut material costs and decrease the weight of components without compromising on performance, reliability or safety.

This whitepaper will demonstrate the Functional Generative Design workflow which won first prize at the Sandia National Laboratories Topology Optimization Roundtable. For the challenge, an automotive structural component was designed using this workflow for three different manufacturing methods—additive manufacturing, casting and 3-axis milling. In all three cases, a design that meets all the specifications was produced, tailored to the demands of each manufacturing method.

INTRODUCTION

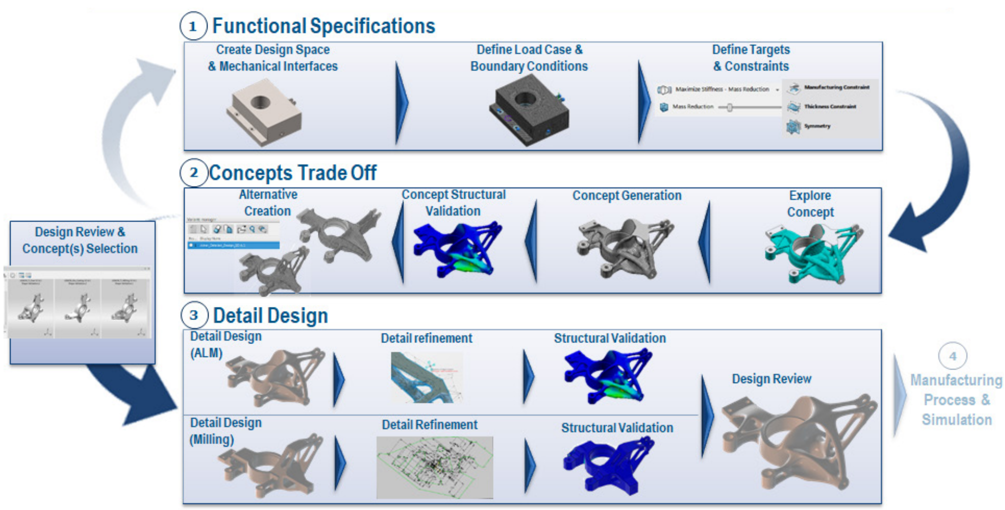

Figure 1: Overview of the Functional Generative Design workflow.

Companies developing new products are constantly striving to optimize their designs. This can mean reducing weight, increasing stiffness, reducing costs or optimizing material usage. It is a competitive world and customers and competitors are always demanding suppliers set new levels of performance and price. This pressure is increased by recent trends for wider portfolios and personalized products, which means more design work with faster development times. Environmental awareness is also leading to new needs for lighter products, less material use and more energy efficiency.

Virtual testing using simulation is well established as a way to analyze designs before manufacturing in order to ensure they meet targets and comply with regulations, and to gain insight into possible design improvements. Modern software and hardware has made virtual testing much more powerful, and it can now be combined with optimization for a fast, powerful way to determine the best solutions.

In topology optimization, the user begins by specifying the targets and constraints for the design. These can include dimensions, weight, material properties, manufacturing process, strength, displacements, and fixed points. These target values can be combined—for example, minimizing weight while keeping displacement below a critical value. The software then uses simulation to analyze the sensitivity of these values to changes in the design. Using this information, the optimization tool determines a configuration that satisfies the target values. This process can result in significant lightweighting of the design and ultimately a product that meets or exceeds all the requirements.

Introducing topology optimization, powered by simulation, from the beginning of the development process can save time and money by allowing designers to make the right decisions earlier in the concept phase. Engineers can balance the trade-offs between numerous different requirements and even find innovative new designs that can improve performance across different categories.

Workflow example:

With considerable interest in topology optimization, Sandia National Laboratories hosts the USACM Topology Optimization Roundtable event. The 2019 roundtable included a challenge to demonstrate the power of various optimization procedures. The first prize in this event was won by the Dassault Systèmes Functional Generative Design workflow, powered by the **3D**EXPERIENCE® platform.

CATIA Functional Generative Design offers a single integrated solution combining design, simulation and optimization—as well as direct links to additive manufacturing process planning tools.

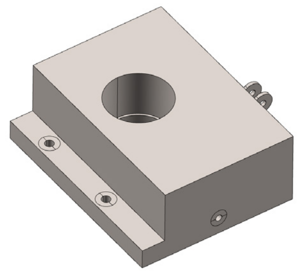

Figure 2: The initial design space, showing the mounting points and frozen areas.

In this case, the challenge was to design a suspension upright for a Formula 1 race car. The design specifications involved several frozen areas for bolts and the axle, and set limits on the allowable displacement to be under 0.12 mm (Figure 1). The part stresses needed to remain below 250 MPa, with the objective of minimizing weight. Three different manufacturing methods had to be analyzed (additive manufacturing, three-axis milling and casting) along with three different materials (titanium, aluminum and steel).

For the purposes of this challenge, all simulations and optimizations were executed on a Linux, 8 core Xeon® 3.0 GHz, 256 GB RAM system using the **3D**EXPERIENCE platform—as an alternative, a local workstation or a cloud computing platform could have been used. The entire optimization process, taking into account all the different manufacturing methods and material properties, was all completed within a single day, as shown in Table 1.

Manufacturing method	Simulation setup	Optimization setup	Compute time	Concept shape validation	Detail design CAD construction time	Detail design validation	Total
ALM	02:00	00:15	03:10	00:15	00:45	00:15	06:40
Milling	*02:00	00:15	03:32	00:15	01:00	00:15	07:17
Casting	*02:00	00:15	01:46	00:15	01:00	00:15	05:31

Table 1: Turnaround times for the designs. *The simulation was only set up once, and reused for all variants, reducing total turnaround time for the 3 methods combined.

Once the objectives and constraints were setup, the Tosca optimization could then be executed. Iterated simulations calculate a topology that meets all the requirements, offering a "topology density distribution" design concept for the next stage of design (Figure 3).

The topology density distribution is loaded in CATIA and quickly and automatically converted into a sub-division surface with a single mouse-click. If desired, the surfaces can be tweaked and the initial optimization load cases are regenerated automatically for continuous validation of the design. The surfaces are then combined into a reconstructed solid CAD part with no user interaction required. (Figure 3)

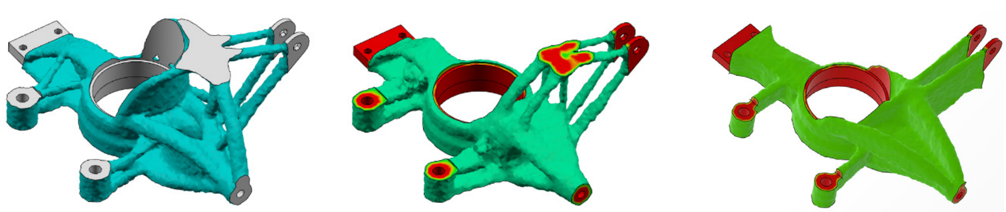

Figure 3: Initial optimization results for AM, milling and casting.

A final trade off study can then be performed comparing the optimized designs in order to find the best performing design or the one that offers the best value for the cost. In this case, the best performing option turned out to be the additive manufactured design made of titanium.

The model is then prepared for manufacturing. For the additive manufacturing optimized design, direct modeling tools including tube and strip drawing are used to create the smooth detailed design surface (Figure 4). The surface is automatically closed to a body and split to ensure that it remains fully within the design space. For milling, the milling profiles are computed and approximated from the optimization result mesh. The cutting tool dimensions are also considered ensuring that the design is feasible for a specific milling process (Figure 5). Standard modeling features like sketches and pockets are used to remove material from an initial milling block. The obtained CAD concept design can easily be manually edited further in the CAD system.

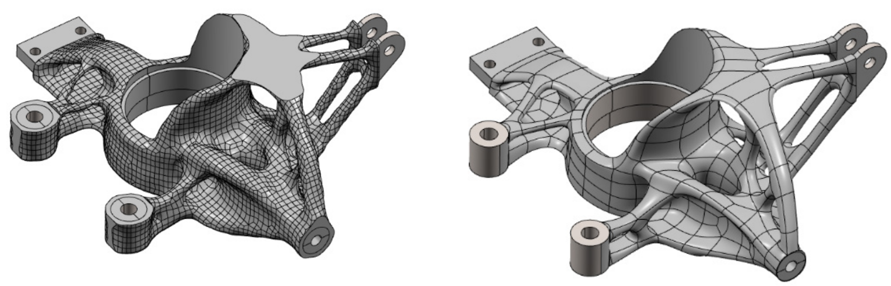

Figure 4: Initial design for the ALM variant (left), and refined CAD model (right)

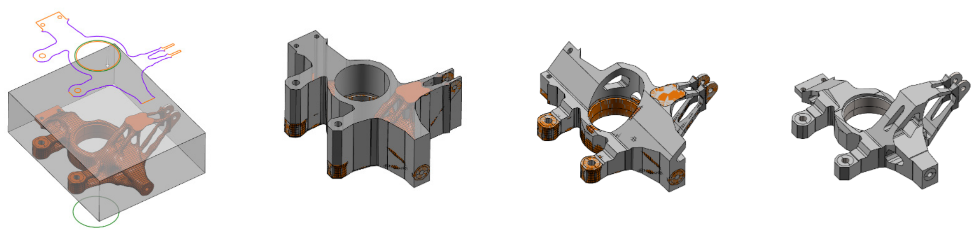

Figure 5: Converting the concept into a design that can be manufactured by 3-axis milling.

The final design can then be used to plan the manufacturing process. For example, the end-to-end Additive Manufacturing solution on the **3D**EXPERIENCE platform plans the print process and simulates the build in order to calculate temperatures, distortions and residual stresses. For more information, see the whitepaper Achieving repeatable, high-quality additive manufacturing builds with simulation.

CONCLUSION

Topology optimization helps engineers to hit targets and to find innovative new solutions to problems such as increasing strength and reducing weight. CATIA Functional Generative Design brings together design, optimization, simulation and process planning tools to offer a single integrated workflow. This was used successfully in the Sandia National Laboratories USACM Topology Optimization Roundtable challenge to design a high-performance automotive component, and has applications in many other industries including aerospace and defense, industrial equipment, high-tech and home and lifestyle. Using CATIA Functional Generative Design can accelerate design cycles, reduce product weight and material costs, and enable new levels of performance.

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