SOLIDWORKS

3DEXPERIENCE®

DESIGN THROUGH ANALYSIS: IMPROVING PRODUCT DESIGN AND AUTOMATING MANUFACTURABILITY WITH TOPOLOGY OPTIMIZATION

White Paper

OVERVIEW

The availability of new manufacturing technologies—combined with demands for greater product development automation, innovation, and throughput—creates both challenges and opportunities for today's product designers. Tasked with delivering higher fidelity initial designs in order to minimize the delays and cost overruns associated with late-cycle performance and manufacturability issues, designers increasingly face the challenges of better understanding design behavior and evaluating the most suitable manufacturing approach while they design. Fortunately, CAD-integrated topology optimization tools, such as those included with SOLIDWORKS® Simulation Professional and SOLIDWORKS Simulation Premium analysis software, provide a transformational technology that can help you quickly and easily generate the optimized shape for a particular design based on the requirements of its operating environment and the production technique utilized. With the ability to conduct fast topology studies, designers have opportunities to automatically generate the optimal shape for a specific design; to quickly take advantage of new manufacturing techniques; and to ultimately satisfy demands for greater product development automation, innovation, and throughput.

DASSAULT SYSTEMES

MANUFACTURING ADVANCES ENHANCE THE BENEFITS OF TOPOLOGY OPTIMIZATION FOR PRODUCT DESIGN

How do you, as a designer, start modeling a new product or component? You might begin with the design for a previous model, a classic engineering shape, or an image in your mind, and then work to improve it. Or, you might use specifications that define the space or envelope in which the design must fit—as well as the constraints and conditions under which it must operate—and then create a design within that space that you believe will function as intended. With any of these approaches, your design decisions are typically based on your experience and knowledge of traditional machining and manufacturing requirements. In short, your design approach is generally framed by your understanding of the manufacturability limitations of conventional production processes like injection molding and casting, or subtractive manufacturing methods like CNC machining and forging.

These manufacturability restrictions (e.g., undercuts, hollow parts, insufficient draft, etc.) don't apply to today's additive manufacturing and 3D printing technologies, however. With these manufacturing advances, organic shapes that were once thought to be impossible to produce can now be created in a variety of materials via additive manufacturing methods, seemingly liberating designers from the manufacturability constraints of conventional production processes. Yet, conventional subtractive production approaches will continue to be faster, more cost-effective, and of higher quality for many types of parts. What designers truly need is a means for automatically generating geometries that take the specific design space, performance requirements, and manufacturability considerations into account. The solution is CAD-integrated topology optimization.

The ability to generate the optimized shape of a part will help you create innovative, validated designs that are free of both performance and manufacturability issues, whether you choose to use additive or subtractive manufacturing. By delivering higher fidelity designs early in the process, topology optimization tools will also let you help your product development organization embrace a concurrent, collaborative approach to design and manufacturing, enhancing your company's competitiveness.

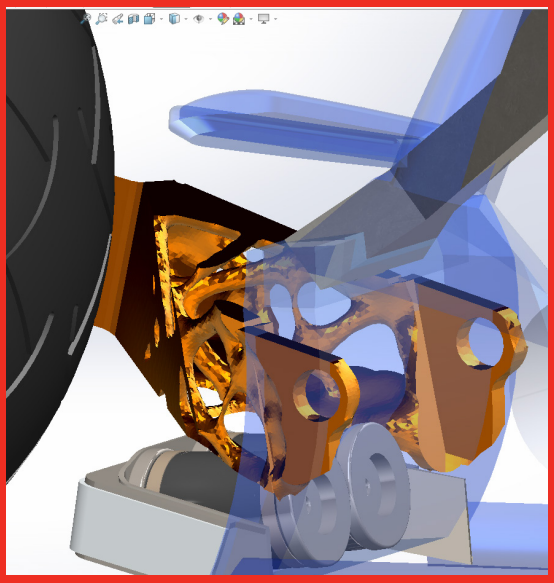
A CAD-integrated topology optimization solution is more than just another example of how product development is becoming more and more automated. It's a capability that transforms, extends, and automates your design toolbox, enabling you to more consistently generate innovative part designs, work smarter, select the most effective manufacturing method, and increase product development throughput. This paper explains how.

A NEW DESIGN PARADIGM

TODAY | **PARAMETRIC OPTIMIZATION**

TOMORROW | **TOPOLOGY STUDY**

Historically your designs were limited in parametric optimization. Designs were optimized based on the parameters inside of existing CAD, sketches, and features. With Topology Optimization, today, and moving forward, you're able to break the restriction on parameters and fully explore your design space, resulting in more organic and exiting models capable of taking advantage of new manufacturing methods not possible with parametric optimization.



a case in point

TARSO MARQUES CONCEPT DRIVES CUSTOM VEHICLE DEVELOPMENT WITH TOPOLOGY OPTIMIZATION

Following his retirement from professional racing, former Formula One racing driver Tarso Marques founded Tarso Marques Concept to develop custom automobile and motorcycle designs that embody his vision for combining elegance with power. Marques initially had difficulty communicating his vision to his design and engineering team, resorting to hand sketches and clay modeling, which took too much time and proved to be ineffective.

"When I discovered SOLIDWORKS, it changed my life," Marques stresses, noting that using SOLIDWORKS 3D CAD software improved his ability to convey his vision to his team.

Marques believes that adding the new topology optimization capability in SOLIDWORKS Simulation Professional software to his SOLIDWORKS CAD implementation will help him create the perfect balance between component aesthetics and performance on his custom-designed vehicles. The shape generated from the topology process can be used as an inspiration for traditional or additive manufacturing.

To Marques, SOLIDWORKS topology optimization is a "truly transformational" technology that will change the way his company designs and builds vehicles, resulting in stronger, lighter, and better-looking parts that deliver high-end performance.

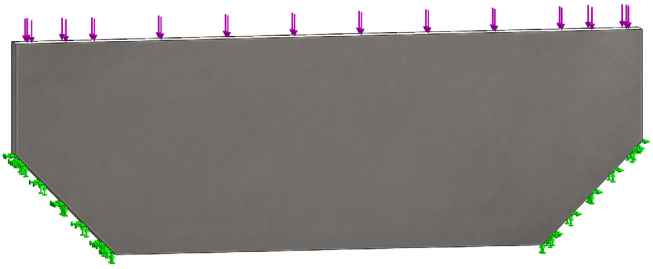
TOPOLOGY OPTIMIZATION: WHAT IS IT?

Not to be confused with topography, the arrangement of the natural and artificial physical features of an area or surface, topology is a branch of mathematics that is concerned with the spatial properties of geometric figures that do not change when the figure is twisted or stretched in certain ways. In the context of design, a topology study explores design iterations of component geometry to satisfy a given optimization goal—such as balancing the weight-to-stiffness ratio, minimizing mass, or minimizing maximum displacement—based on specific loads and geometric constraints, including those imposed by the manufacturing process used.

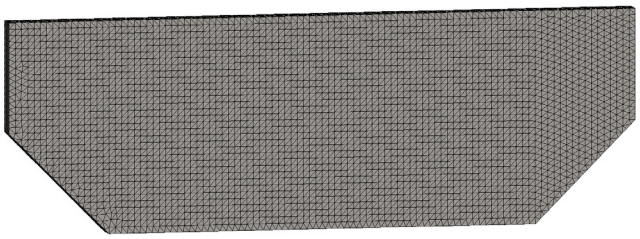
As a designer familiar with CAD modeling tools, you will find CAD-integrated topology optimization easy to use because of its integration inside your primary design environment. You simply input information about your design—including the size of your design space, applied loads, constraints, boundary conditions, and intended manufacturing method—and then let the algorithm automatically generate a mesh of the design space and run the optimization loop required to generate the optimized design geometry.

Instead of spending time creating a model, you can use the topology-optimized model as a starting point or reference, enabling you to save time while simultaneously improving performance. You can also use topology studies to generate new ideas, explore varying design options, and help refine your designs by letting you know where to add material and where to take it away. In addition to helping you create higher fidelity designs, topology studies allow you to evaluate other potential production methods. And because the topology-optimized model is integrated within your design environment, you will quickly be able to finalize your designs with the confidence that there are no performance or manufacturability issues, enabling others in the design-through-manufacturing process to leverage your design data at an earlier stage.

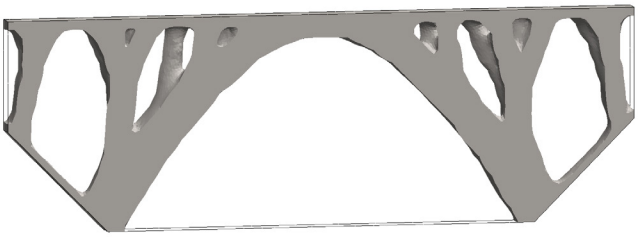
Design Space



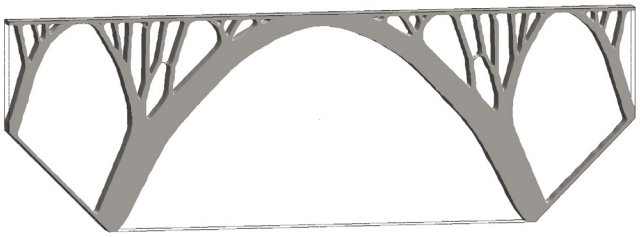
Mesh



Optimized Shape



Optimal Structure



TOPOLOGY OPTIMIZATION: HOW DOES IT WORK?

In simplest terms, a topology study utilizes an iterative algorithm to run a design optimization loop to generate the best possible shape based on the loads, constraints, boundary conditions, and manufacturing controls specified. The topology study tool provided with SOLIDWORKS Simulation Professional and SOLIDWORKS Simulation Premium analysis software performs a nonparametric topology optimization of parts, running in the background in a couple of hours.

Using an automatically generated finite element analysis (FEA) mesh of your design space and your inputs of loads, constraints, boundary conditions, and manufacturing controls, the topology optimization seeks a new material layout by redistributing material to satisfy all the structural, mechanical, and manufacturing requirements. It determines how to distribute material by removing the "soft" elements that do not contribute to the stiffness of the component for the particular load scenario, boundary conditions, and manufacturing controls. For each element, the optimization algorithm couples the material's Young's modulus with a relative mass density factor ranging from 0.0001 (for a void element without any load-carrying capacity) to 1.0 (for a solid element with load-carrying capacity). Elements with low relative mass densities (< 0.3) are considered "soft" elements. These elements do not contribute to the overall stiffness of the component, and they can be safely removed. Elements with high relative mass densities (> 0.7) are considered "solid". These elements contribute the most to the overall stiffness (as a measure of the load-carrying capacity) of the component, and they should remain intact in the final design. The "solid" elements distribute the applied loads more effectively than the "soft" elements.

You can use topology studies to optimize designs based on three optimization goals: 1) best stiffness-to-weight ratio; 2) minimize maximum displacement; 3) minimize mass with displacement constraint. This process will create a 3D material layout based on the optimization goal and geometric constraints that you define. This is typically a very organic shape that may be impossible to create using traditional techniques. You can apply a second set of geometric controls related to the planned manufacturing process to prevent the formation of undercuts, hollow parts, shapes with insufficient draft, and other manufacturability issues.

TOPOLOGY OPTIMIZATION: HOW DOES IT BENEFIT DESIGNERS?

In an increasingly global market, competitive presssures create demands on manufacturing organizations for increased innovation, automation, and throughput across every department, but especially product development. These demands are already affecting the work of designers, with greater expectations for more complete designs with few, if any, performance or manufacturability surprises encountered late in the product development process. Delivering higher fidelity designs earlier in the process puts additional demands on you as a designer that require you to work faster and smarter by extending your design toolbox to include SOLIDWORKS CAD-integrated topology optimization tools.

Save Time and Improve Designs Simultaneously

Using topology studies will help you design more innovative, safer, better-performing, and less-costly-to-manufacture parts faster and more consistently because it enables you to skip some of the time-consuming aspects of initial design and factor in desired performance and manufacturability. By automatically generating a model of the optimal shape for your specific design requirements, topology optimization enables you to start work on an existing model, allowing you to spend your time focusing on design refinement rather than model creation. Topology studies also help you eliminate guesswork associated with avoiding design performance and manufacturability issues because they will have already been addressed as part of the optimization loop. SOLIDWORKS topology optimization will not only give you greater confidence in the validity of individual designs - it will also enable you to create more designs of higher quality without working longer.

Creating Smaller, Lighter-Weight Components

In addition to helping you save time and improve design performance, SOLIDWORKS topology optimization will bolster efforts to create smaller, lighter-weight components. Minimizing mass is important for designers affected by the ongoing trend towards miniaturization, with some consumer products continuing to get smaller and smaller. Reducing component weight and cutting material usage also have long been goals in many industries, such as automotive and aerospace. By giving you the ability to optimize your design to the best stiffness-to-mass ratio or to minimize mass—and thereby weight—using maximum allowable displacement as a constraint, topology optimization automates your efforts to create smaller, lighter-weight components, or those that use less material.

Modulating Part Stiffness

For many types of parts, making sure that the design is stiff or rigid enough to perform its intended function is a primary design goal. For other kinds of components, the flexibility of the part—the way it deforms under applied loads—is a key design objective. Depending on the types of products that you design, you may even have "stiff" and "flexible" components within the same assembly. With SOLIDWORKS topology optimization tools, you can use the minimize maximum displacement study to make parts more rigid by setting stiffer performance targets for maximum displacement in your design, or to make components more flexible by setting more pliable performance targets for maximum displacement in your design.

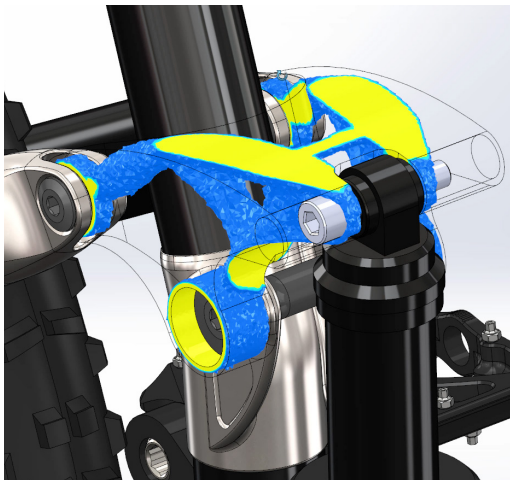
Additive or Subtractive Manufacturing?

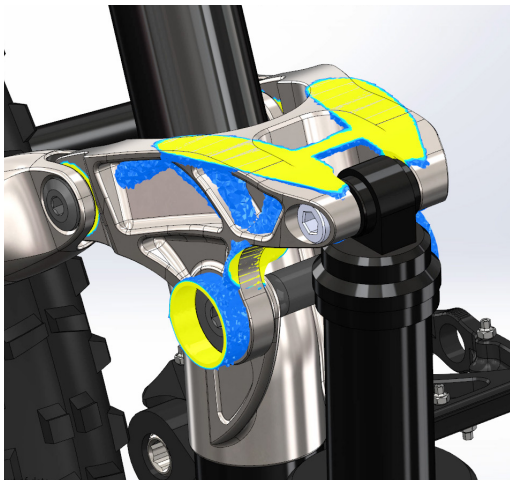
The advent of additive manufacturing technologies—through which a part is created by adding material layer by layer rather than machining, removing, or subtracting material to create component features—certainly makes the ability to use topology optimization to generate and produce organically-shaped parts more beneficial. But the benefits to designers of SOLIDWORKS topology optimization tools extend beyond the ability to make crazy-looking functional parts. By providing you with a solution for assessing manufacturability according to the unique

requirements of a specific production method, topology optimization can help you identify both the best-performing design and the most suitable manufacturing method for every design. This will allow you to design for traditional subtractive manufacturing as well as take advantage of new additive manufacturing approaches when warranted.

Using Optimized Shape for Reference

You can use SOLIDWORKS topology optimization capabilities to either generate the initial model for your design or as a reference overlay for use with an existing design. You can then use this optimized shape to improve your existing design, 3D print your design, prepare your design for machining, or guide additional parametric optimization of the part design in preparation for computer-aided machining (CAM). Using the optimized shape as a reference for other design and manufacturing preparation functions is another time-saving benefit of topology studies that will help you consistently create high-fidelity, innovative designs that are cost-effective to produce and free of manufacturability issues.



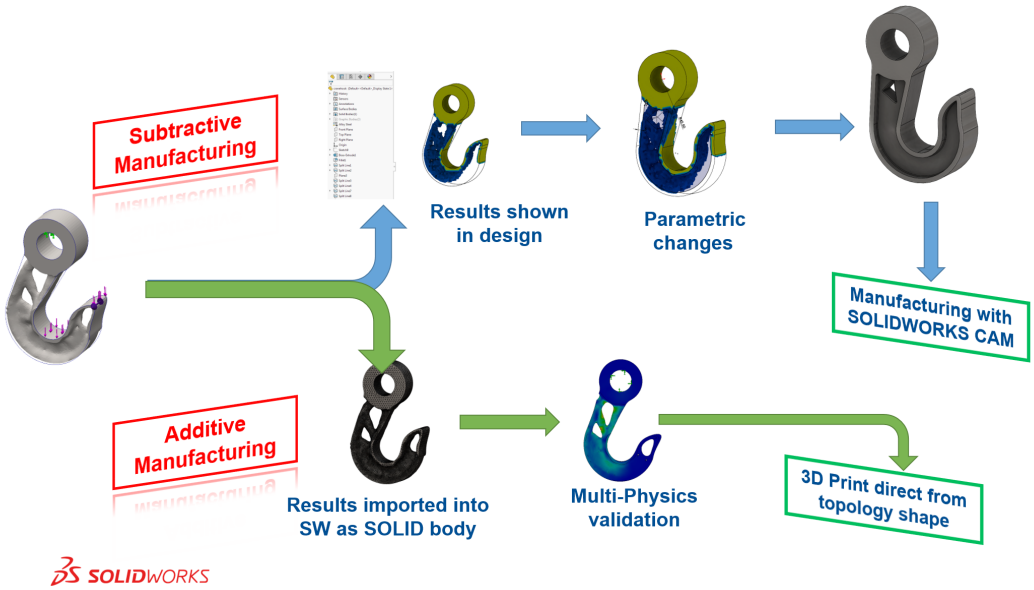


Completely Automated Meshing

One of the ways that SOLIDWORKS topology optimization tools save you time is by completely automating the topology optimization process, including meshing, solving, and post-processing of results. All you need to do is enter known information for your design, including the size of your design space, applied loads, constraints, boundary conditions, and intended manufacturing method. The SOLIDWORKS topology optimization algorithm will then automatically generate a mesh of your design space and run the optimization loop required to generate the optimized design geometry. Because this technology has been automated, you can quickly begin using this powerful tool without having to invest in training courses or additional skills development.

Optimization Loop Runs in Background

In addition to automating the entire topology optimization process, the SOLIDWORKS topology optimization solution conducts its computations in the background, freeing you up to continue working. This is an important benefit as past topology optimization approaches were both slow and computing-resource-intensive, taking over a computer workstation and preventing users from doing much else until the solution completes. With SOLIDWORKS topology optimization, the optimization loop runs in the background in a couple hours or less, allowing you to continue to use your laptop or computer workstation while the solution computes in the background.



EASILY INCORPORATE TOPOLOGY OPTIMIZATION INTO PRODUCT DEVELOPMENT WITH SOLIDWORKS SOLUTIONS

With the topology optimization capabitilities of CAD-integrated SOLIDWORKS Simulation Professional and SOLIDWORKS Simulation Premium analysis software, you can easily incorporate topology studies into your product development process. This will not only help your designers save time and improve quality, but also benefit all of the downstream functions that rely on access to high-fidelity design data early in the design-to-manufacturing process.

CAD-Integrated Topology Optimization Generates Design Starting Point

Every manufacturing organization wants to shorten product time to market, which is why many product development organizations work to maximize design reuse. With CAD-integrated SOLIDWORKS topology optimization tools, you can improve your product development organization's efficiency even further by beginning your design process with a topology-optimized model of a part that is completely free of performance and manufacturability issues. You can use topology-optimized models as starting points to design parts, as a guide for refining your designs by providing insights into where you can add or remove material, as a reference for preparing your designs for machining, and to drive additive manufacturing. Because topology studies validate your designs in this way, you will also realize quality improvements in conjunction with productivity gains. Existing SOLIDWORKS CAD users can quickly and easily begin using SOLIDWORKS topology optimization tools because both SOLIDWORKS Simulation Professional and SOLIDWORKS Simulation Premium analysis software are completely integrated within the SOLIDWORKS 3D CAD modeling environment.

Downstream Functions Benefit from Early Use of Topology Optimization

It's not just product designers who benefit from incorporating SOLIDWORKS CAD-integrated topology optimization tools into your product development environment. Designers can use the topology-optimized model, which is free of performance and manufacturability issues, to create higher-fidelity designs sooner in the process. Designs reside within the integrated SOLIDWORKS 3D product development environment. Other functional departments in the design-through-manufacturing process who need to leverage design data to complete their function can do so sooner, extending productivity gains to many downstream functions. These downstream activities include visualization, validation, cost estimating, manufacturing planning, data management, manufacturing, quality control, documentation, packaging development, and marketing. The sooner a design reaches a releasable stage, the sooner all of the downstream departments who need to work with the data can start. CAD-integrated SOLIDWORKS topology optimization tools can help both happen more quickly.

DESIGN HIGHER QUALITY, MORE INNOVATIVE, AND BETTER PERFORMING PARTS WITH SOLIDWORKS TOPOLOGY OPTIMIZATION SOLUTIONS

The introduction in recent years of a range of additive manufacturing technologies has caught the interest of many product development organizations that need to know whether these new production processes have the potential for increasing productivity. That's because the competitive pressures of the global market compel manufacturing organizations to increase innovation, automation, and throughput to gain a competitive edge. This is true across every department, but especially product development, where designers face greater expectations for more complete, higher fidelity designs—free of any performance or manufacturability problems.

Designers can meet these expectations by adding the CAD-integrated topology optimization capabilities in SOLIDWORKS Simulation Professional or SOLIDWORKS Simulation Premium analysis software to your design toolbox. Using SOLIDWORKS topology studies, you can create lighter, higher-quality parts more quickly because you will begin working with the optimal concept for your design situation from the very beginning. This will enable you to ensure greater design fidelity by validating component performance and improving design for manufacturability. You will also be able to assess the viability of new additive manufacturing methods as well as the use of other traditional production techniques. Most importantly, SOLIDWORKS CAD-integrated topology optimization tools allow you to design without the restrictions and limitations of conventional manufacturing processes like injection molding and casting or subtractive manufacturing methods like CNC machining and forging. By automatically generating geometries that take the specific design space, performance requirements, and manufacturability considerations into account, SOLIDWORKS CAD-integrated topology optimization can help you produce the optimal design and select the best means of production, early in the process.

To learn more about how SOLIDWORKS topology optimization solutions can improve your design and manufacturing processes, visit www.solidworks.com or call 1.800.693.9000 or 1.781.810.5011.

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