WHITE PAPER

Realizing your product potential through pervasive simulation and advanced manufacturing processes

Global demand for resources has inevitably led to scarcity. The use of resources also generates significant levels of pollution and waste that are difficult to manage. With an ever-growing focus on sustainability, efficiency, and cost-savings, the economy is changing. Consumers are demanding products that are made responsibly and optimized for energy efficiency. Many businesses are looking for ways to address these global issues using pervasive simulation and advanced manufacturing processes. Manufacturing is undergoing transformation. Not only are the production processes becoming more innovative but also new materials and technologies are being incorporated into the manufacturing process. This has led to a shift from conventional manufacturing, which was based on subtractive processes, to a new technology which uses additive processes. Ansys provides new ways of creating optimized parts through topology optimization to unlock the full potential of this new technology. Topology optimization algorithms use mathematical techniques that help engineers optimize product design, freeing up resources and making design decisions earlier and easier. Ansys provides a tool kit to generate structural optimized parts, which removes any unneeded material for maximum part efficiency and cost and energy savings, while simulation enables the printing process to print correctly on the first attempt.

These solutions can help companies realize their product potential while also addressing environmental concerns and meeting their consumer needs.

1. Motivation and Purpose

In many areas of applications, especially electrification and high tech, there is a common trend to save energy and increase efficiency. New manufacturing technologies, such as additive manufacturing (AM), enable the creation of more organic and lighter structures. These structures are created by using topology optimization, which removes unnecessary material and mass to save costs and decrease energy consumption. In this paper, you will find a method for combining topology optimization and lattice infill to create stiffer and lighter structures compared to adding a single lattice infill.

Figure 1: Saving 66% of weight with topology optimized parts

Aconity3D and Ansys partnered to investigate the possible improvement of a known public part – the Alcoa bracket. In 2016, Alcoa Fastening System & Rings (AFSR) called for ideas on GrabCAD to improve the part using suitable tools. Since that time, many engineers and software solutions providers have challenged their approach to create an even lighter geometry than the existing designs.

Seeing the published results, we set the following questions and goals:

1. How easy and agile are Ansys products in exploring and improving design?
2. Can we devise a method to optimize both the lattice infill and the housing efficiently to print it with more ease?

Key: #Structural Optimization, #Lattices, #Topology Optimization, #Printability, #Level Set, #Aconity3D, #Ansys

2. Overview and Introduction to Used Technologies

To answer the self-set questions, we followed a process of simple, fast sanity checks to devise the easiest and most convenient automated workflow. Finally, we plugged in the actual model and let the process generate the best viable part. In Figure 2, the workflow is shown on the Ansys workbench schematic. All processes are connected for automatic updates of the varying parameters without the need of scripts.

We referred to these subsections for subsequent subsections. First, in isolation to show the pros and cons. Later, to demonstrate how the displayed combination of technologies enhances the final solution.

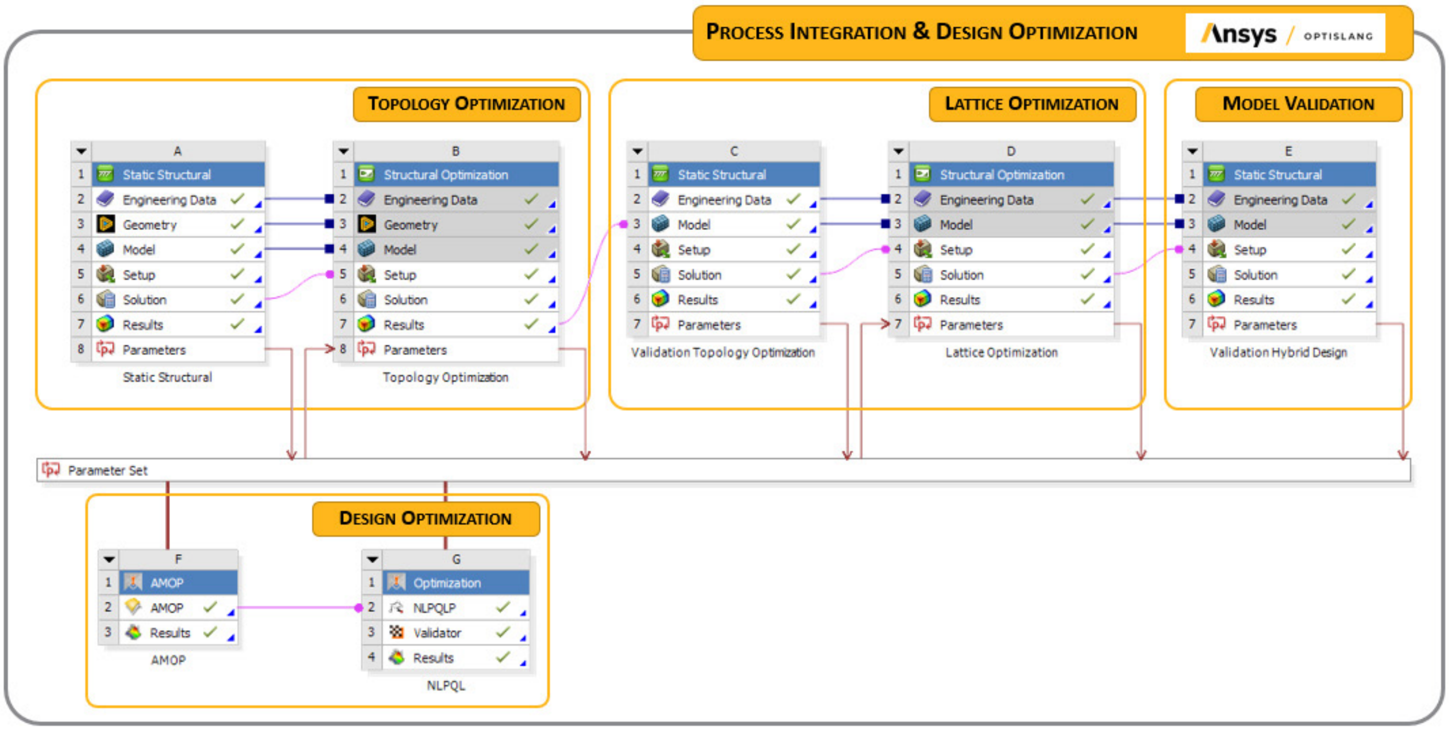


Figure 2: Workflow overview

3.1 Pure Lattice Optimization

Lattice optimization is the substitution of solid material by struts to decrease weight. The outer shape is retained. The AM method and a new casting technology enable the manufacturing of them. Ansys provides various types of lattices for additive manufacturing, and part of the first study was to determine the most suitable.

A simple cube was used to deploy the method, automation, and printability. Aconity3D screened the different lattices regarding printability to reduce the simulation effort. The cubes were inspected regarding the spacing and range of densities of the lattices, and finally printed and evaluated.

In this study, we were able to answer the question about the added printing costs using lattices. We learned that printing lattices inside a part does not incur additional printing costs and bears no difference at all economically compared to printing on the solid material using Aconity3D printing parameters.

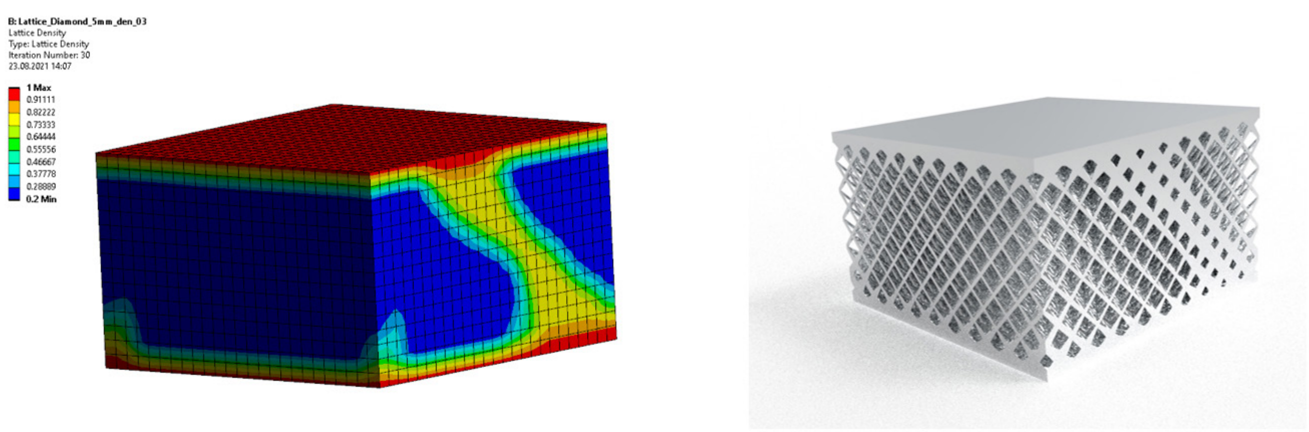


Figure 3: Lattice density distribution in the sample box

In the workflow, the geometries of the sample box and the Alcoa bracket are exchanged, which leads to the density distribution shown in Figure 4.

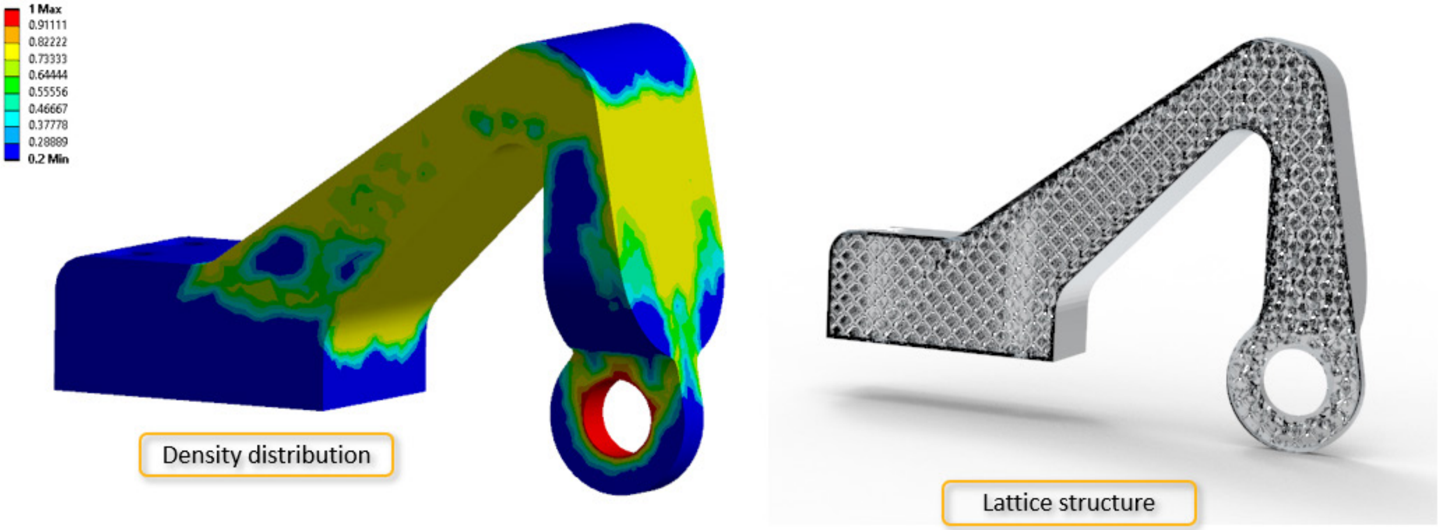


Figure 4: Lattice density distribution in the Alcoa bracket

Checking for part properties

Ansys provides a fast way to check the part for its mechanical properties. Instead of needing weeks on clusters for the calculation of the complex lattice structure, it uses a validated and approved way using so-called knockdown factors*, as shown in Figure 5. The varying mechanical properties function on the initial solid model and recalculate the model in a few minutes instead of geometrically, resolving all lattices and running the simulation for weeks on high-performance clusters.

* *J. Manuf. Sci. Eng. | ASME Digital Collection - Efficient Design-Optimization of Variable-Density Hexagonal Cellular Structure by Additive Manufacturing: Theory and Validation*

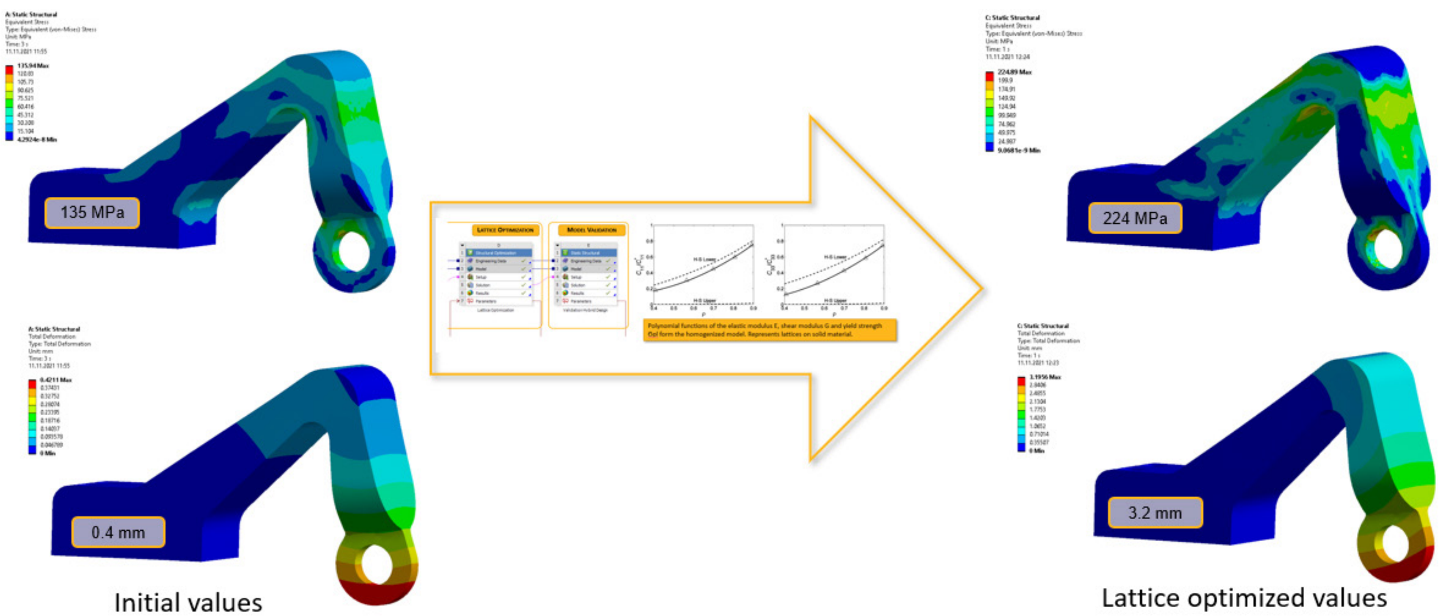


Figure 5: Knockdown factors to accelerate validation calculation for lattices

3.2 Hybrid Design: Combined Topology and Lattice Optimization

The found parameters are the basis for the Alcoa bracket optimization and simulated for two printing orientations: a standard orientation, used by the most engineers (Figure 6, shown left), and another orientation to use the initial geometry shape to minimize the need for supports (Figure 6, shown right). Ansys provides the manufacturing constraint overhang to build – if feasible – a supportless solution.

In addition to the position itself, the solid material to lattice ratio was part of the investigation regarding a stress limit.

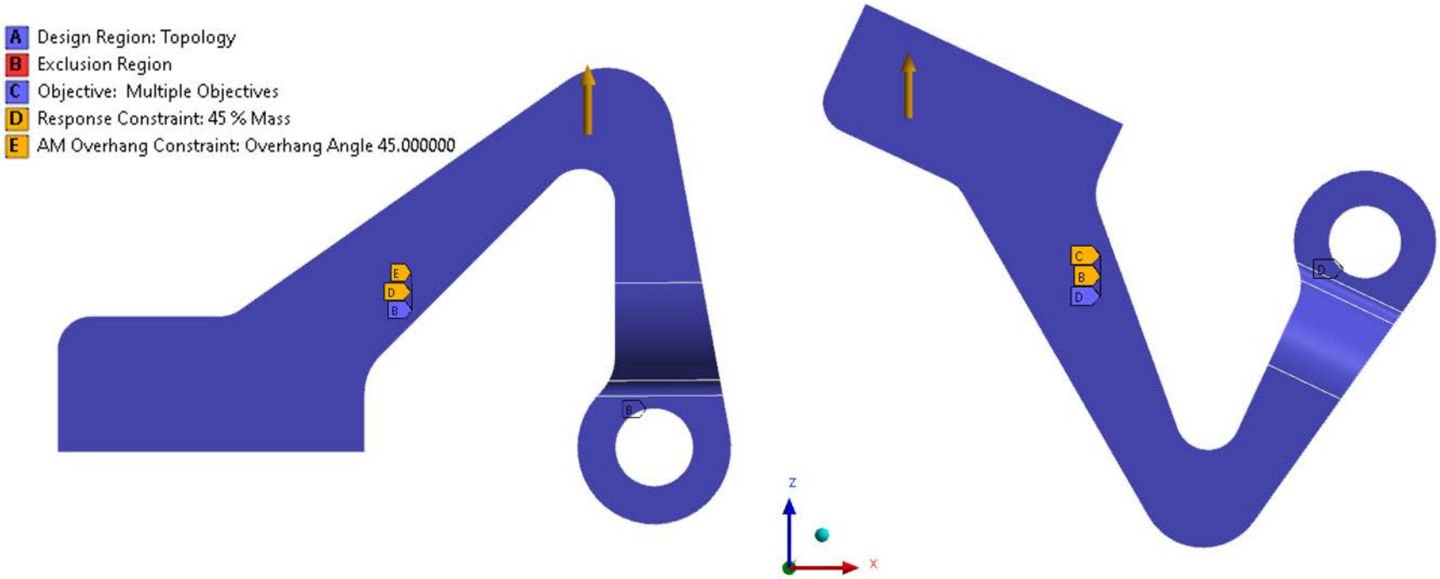


Figure 6: Simulation and printing orientations: standard orientation (shown left), orientation to minimize supports (shown right)

A two-step approach optimizes the outer shape first by using topology optimization followed by the lattice infill (shown in Figure 7). The resulting stereolithography (STL) of the topology optimization is directly transferred to the lattice optimization. This seamless workflow allows an automation for a parametric optimization as described in the next section. Here, the remaining solid ratio of the topology and lattice optimization are targeted to get the lightest and stiffest design constricted by a stress limit.

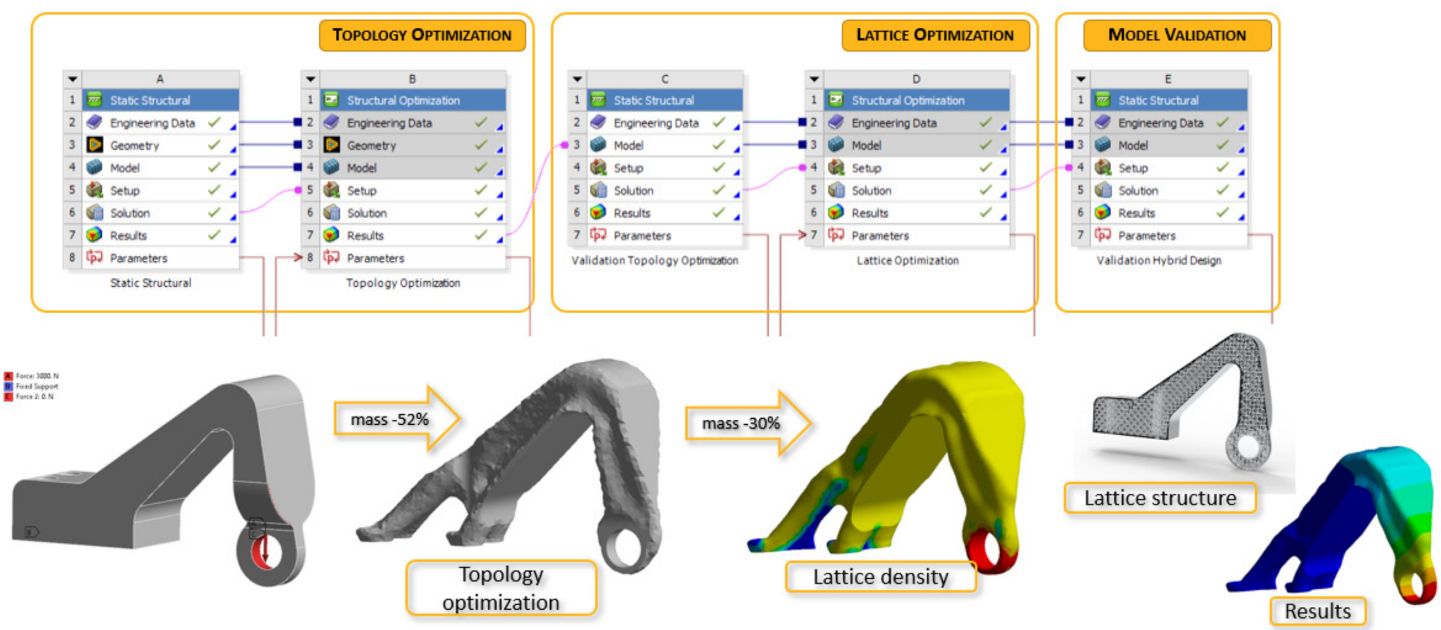


Figure 7: Two-step approach

First step: Topology optimization and new design validation

The initial design is optimized with the objectives to minimize compliance and stress subjected to a mass and overhang constraint. The mass constraint, resulting mass, initial deformation, and equivalent stress are parametrized for the later study.

Second step: Lattice optimization

In the second step, the topology optimization result is validated, and the stress and deformation parametrized. The lattice optimization objective is compliance subjected to a mass constraint. The resulting mass is parametrized and the validation approach, using the knockdown factors, extracts the stress and deformation of the optimized part.

/ 4. Parametric Optimization

To save time from computing hundreds of design variations, Ansys optiSLang calculates a smaller number of variations, which are expressed as a mathematical response surface (Figure 8). This covers all possible solutions, including those not calculated, and permits an optimization of the solid and lattice ratio within minutes. By keeping the equivalent stress in the linear region, the minimum weight is the combination of the target and constraints. The simulations run overnight on Ansys Cloud.

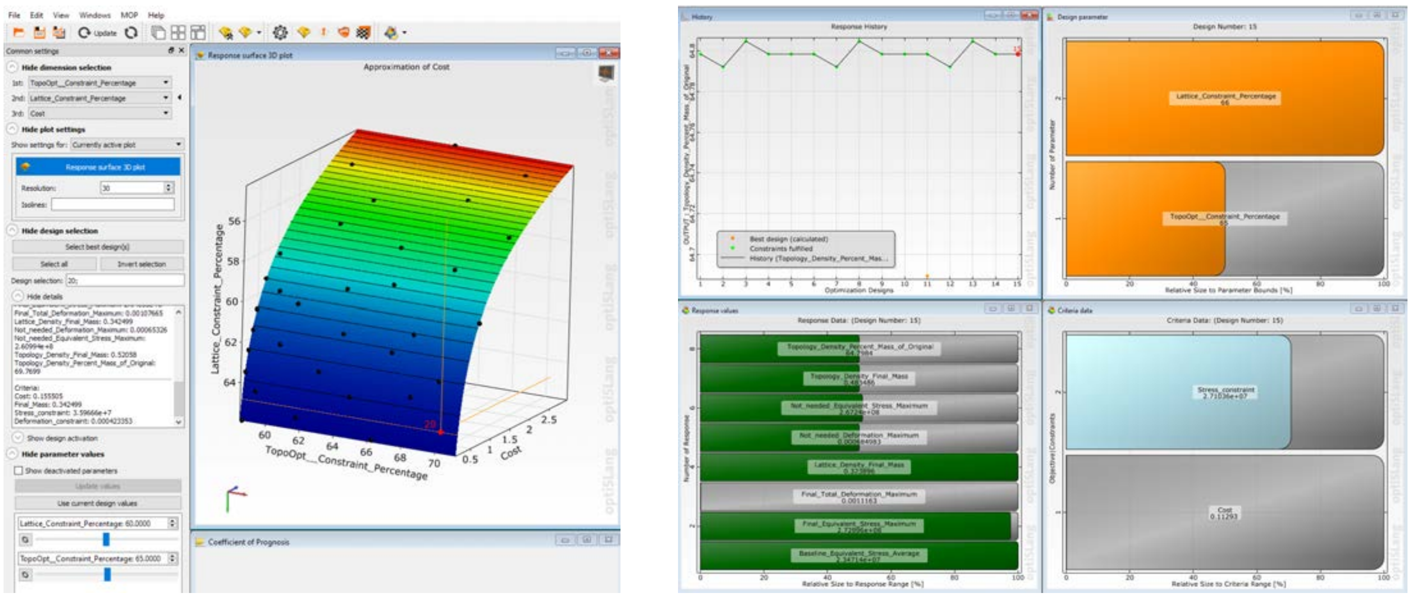


Figure 8: Method of procedure (MOP)/response surface

Transfer to the Additive Printing Process

The workbench framework automatically transfers the simulation results into Ansys SpaceClaim and within one platform, it offers various tools from creating geometry to writing out a ready-to-print file. The results for the new Alcoa bracket are converted back to computer-aided design (CAD) and holes for powder removal are inserted based on experience, knowledge, and visibility of Aconity3D. Finally, the AM tools in SpaceClaim help to define the final orientation on the build plate, creation of supports and build file itself, and are ready to send to the printer for production or simulation of the additive printing process using Ansys Workbench Additive.

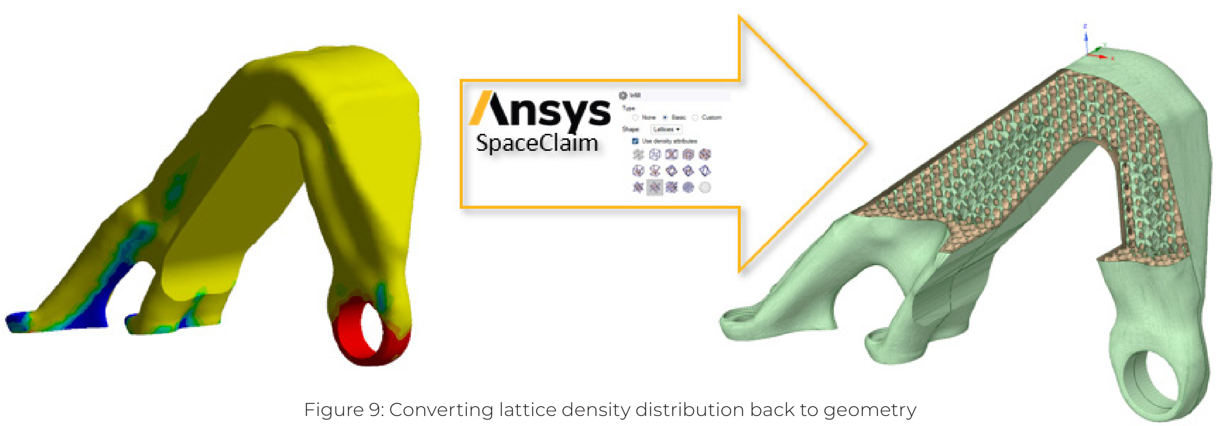


Figure 9: Converting lattice density distribution back to geometry

/ 5. Printing the New Alcoa Bracket

Aconity3D Workflow

Ansys' fully automated optimization approach incorporates general design rules, feature size restrictions, and support guidelines provided by Aconity3D. After optimization, the component is transferred to Aconity3D as an STL file.

The subsequent preparation and printing process is shown in Figure 10.

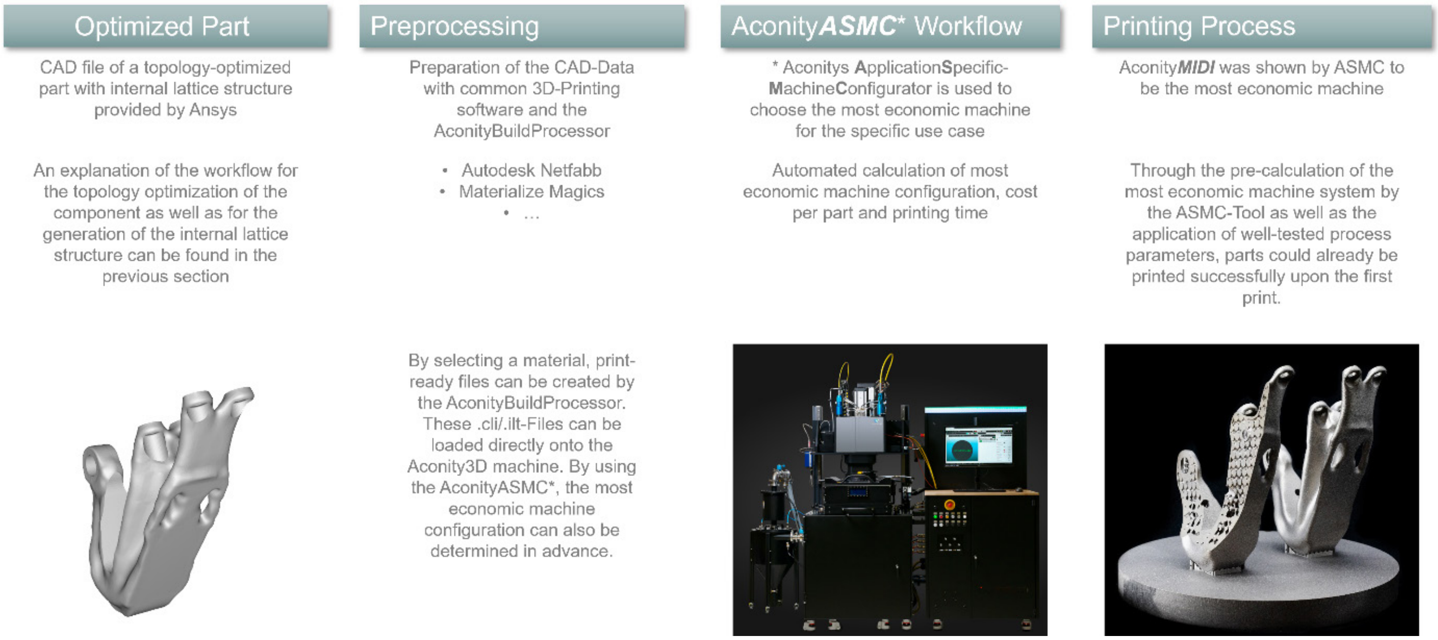


Figure 10: Preparation and printing process

In the preparation process, a common layer interface (.cli) and its compressed version (.ilt) files are first created using common 3D preprocessing software and the Aconity build processor. The internal lattice structures are prepared in such a way that the printing process can be carried out as efficiently as possible, reducing nonproductive periods typically occurring during exposure of small geometric features.

Subsequently, the Aconity*ASMC* tool is used to calculate the most suited machine configuration for the respective application as well as printing time and costs per part. By selecting adapted process parameters for the internal lattice structure, the printing time of the optimized part can be reduced by 8.5% compared to a completely solid part.

The printing process was carried out on the Aconity*MIDI* based on the previous ASMC calculations. The Aconity*MIDI* is Aconity3D's approach for a flexible production system with process monitoring options by means of high-speed imaging and pyrometry aimed at facilitating improved quality parts for critical applications according to certified process routes. This allows for flexible pre-testing and subsequent prototyping while continuously monitoring the printing process using high-speed pyrometry and powder bed imaging.

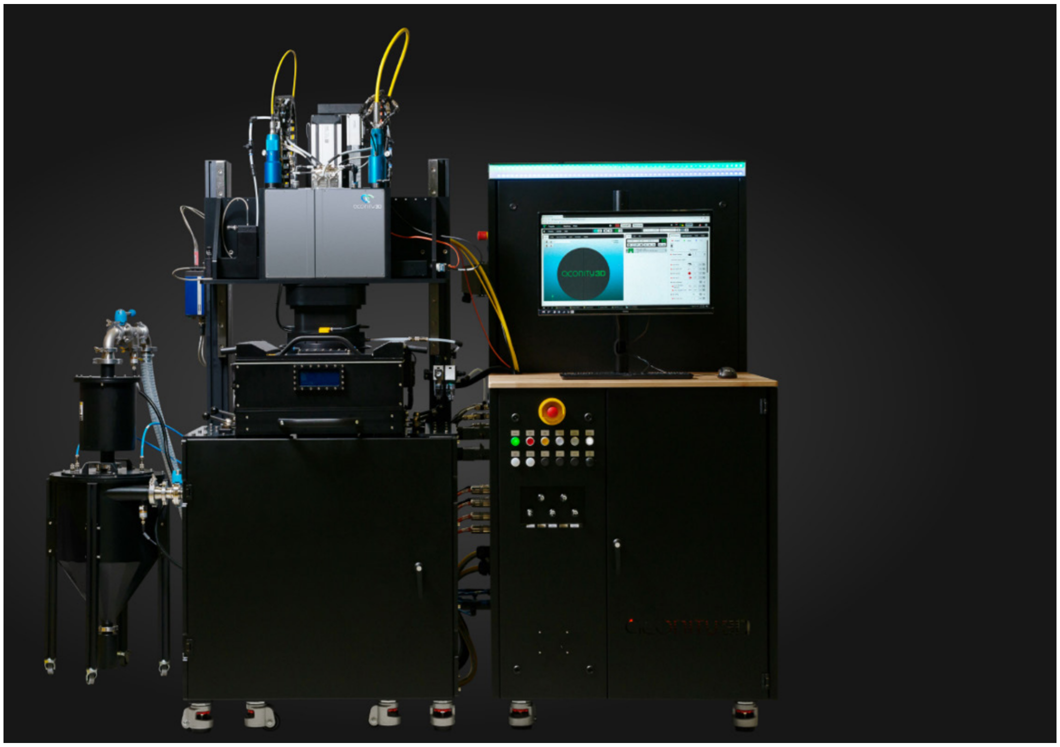


Figure 11: Aconity3D printer setup

Printing results

Due to part optimization and the application of well-tested process parameters, the part was successfully built upon the first print. The actual printing time, including inertization and machine setup time, was determined to be only approximately 1.3% greater than the ASCM calculation, which underlines the practical applicability of this tool for accurate machine selection and production planning.

This joint approach by Ansys and Aconity3D allows users to put their AM business case into practice even faster than before. Saving part volume and printing time not only saves money, but also helps to preserve valuable resources. Enjoy the following impressions of our demonstrator part!

Figure 12: Close-up of printed part

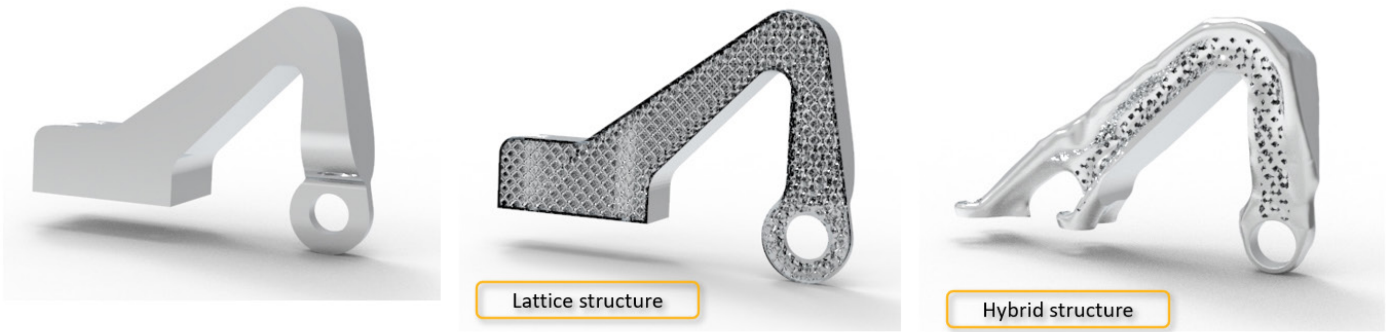
Figure 13: Parts on plate, first cutted by Wire EDM

Figure 14: Close-up of cutted Wire EDM part

6. Summary

With the combined knowledge of simulation and printing, the bracket can be improved in a fast turnaround time and demonstrates the capability and printability of lattice inside structural optimized parts. It also demonstrates the efficiency of the structural optimization itself which is only improved by internal lattices. The manufacturing constraint overhang creates a nearly supportless solution avoiding post-processing of the print.

The study reveals that the combination of topology and lattice optimization leads to a higher performance part. It generates stiffer and lighter structures compared to a single lattice infill.



https://grabcad.com/challenges/airplane-bearing-bracket-challenge

	Initial part	Lattice	Hybrid
Weight [g]	339	121	114
Deformation [mm]	0.4	3.2	2
stress	95	224	206
ΔWeight [%]		64	66

Figure 15: Summary of results of pure lattice and hybrid optimized bracket

Company Profile

Advancing AM requires system configurations and processing strategies far beyond conventional AM machine technology.

With a profound background in powder bed fusion research, Aconity3D's staff is experienced in developing, building, using, and continuously extending their own laser beam melting (LBM) systems for more than a decade. Since 2014, the most successful former prototypes as well as their successors are available to the market.

As understanding new processes, discovering unknown effects, and developing materials with advanced properties requires an infinite degrees of freedom in terms of applicable process parameters, Aconity3D's LBM machines offer complete flexibility with hardware and software.

Since applications and production environments vary, Aconity3D machines offer a variety of optional modules and useful accessories – starting with external process preparation and powder handling modules to preheating from 200-1200 °C and industry-leading process monitoring systems suited for sustainable quality assurance.

At the core of each machine, the control software Aconity*STUDIO* allows users to apply established LBM processes with a few simple clicks or create their own elaborated process and exposure sequences via editable scripts. Aconity3D's open application programming interface via Python allows for triggering external and/or third-party hardware and software modules, gathering data from both internal and external sensors, and can be used to adapt the LBM process, if necessary, within individual scanning vectors from layer to layer or from build job to build job.

Beginners to advanced professionals leverage Aconity3D tools to generate in-depth process knowledge and understanding. This core know-how can be directly applied in creating unique selling points for the tools.

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