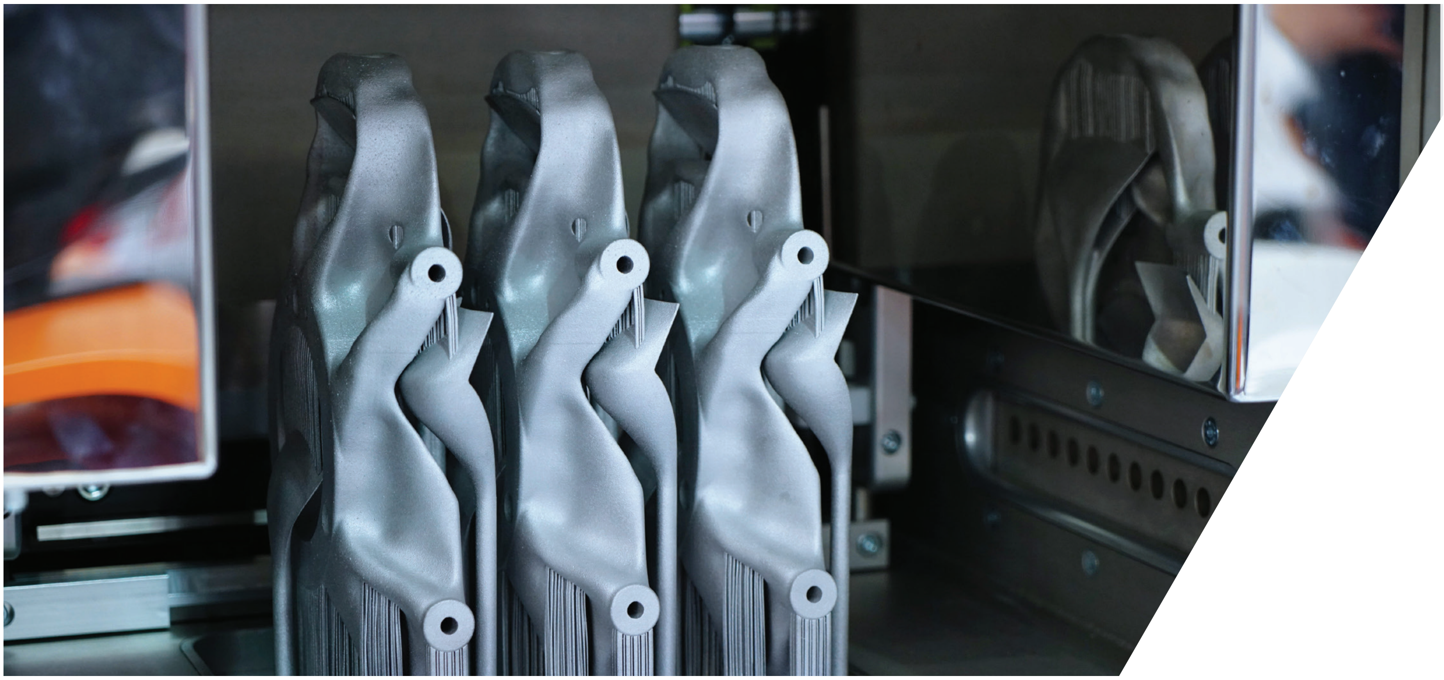


MACHINE LEARNING-DRIVEN TOPOLOGY OPTIMIZATION APPROACHES

Overview
Topology optimization helps manufacturers and designers achieve lightweight, structurally sound structures. It can help designing lighter products while maintaining high strength – as such, the demand for topology optimization has been increasing with the popularity of 3D printers that allow for less manufacturing constraints.

About the Customer
Chuo Engineering is engaged in design and development work primarily in the aerospace field, but it also does work in the automotive, industrial machinery, telecommunications, home appliances, medical equipment, and software sectors. In the aerospace sector, the company engages in a range of areas, including the design and development of airframes and engines for rockets and aircraft.

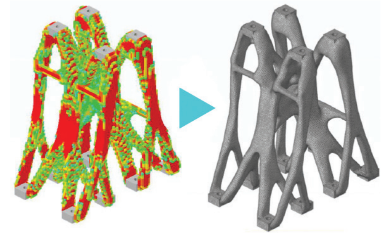
Their Challenge
Chuo Engineering, which has utilized topology optimization in the design phase for years, recognized two major challenges with a traditional topology optimization approach.

The first problem is that users determine constraint conditions up front, so it takes a lot of time and effort to repeat the analysis many times while changing the conditions and deriving the desired performance. Although users enter volume fraction and minimum member spacing in advance, analysis results only represent the optimal outcome under those conditions. Thus, it's difficult to determine what is truly the optimal shape.

54% ▲
WEIGHT SAVINGS

93% ▼
TIME SAVINGS

The second problem is that the analysis results include regions with intermediate density elements. In topology optimization using the density method, the result is expressed as a material density distribution, where the necessary part is 1.0, the unnecessary part is 0.0, and intermediate density elements with values in between are included, up to a certain density threshold. If there are too many of these elements, the final shape may have too much weight, so it is preferable to avoid generating them. Therefore, the analysis may be repeated while changing the constraints until the results generate as few intermediate density elements as possible.



Solution

To solve these topology optimization challenges, Chuo Engineering turned to machine learning.

To determine the constraints, it used regression analysis with machine learning to clarify the causal relationship between the constraints and the analysis results, and to quickly find the optimal constraints. The engineering team used Altair® HyperStudy® to run topology optimization analysis with appropriate values within the constraints to collect sampling data for machine learning. They then used the sampling results to perform a regression analysis using Bayesian optimization, and applied the resulting regression model to estimate the appropriate constraints, which they analyzed in Altair® OptiStruct®. By repeating this process, the team eliminated unnecessary analyses to find the best results. Furthermore, Chuo Engineering built its own “AI auto-execution tool” using Python scripting to automate this series of steps.

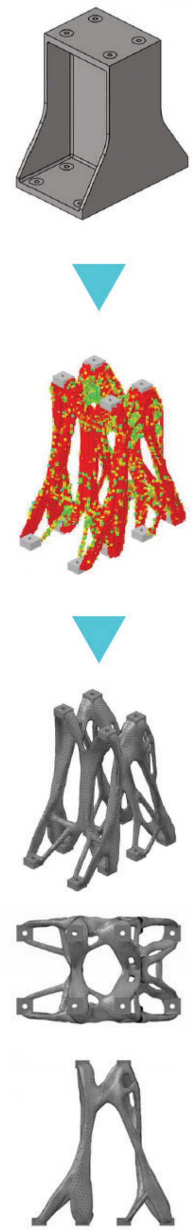
For the second problem (identifying the ideal density threshold), the engineering team used Altair Knowledge Studio to analyze solutions with fewer intermediate density factors among the similarly optimal results obtained in these processes to derive optimal constraints with fewer intermediate density factors through cluster analysis.

Impact/Value

With these methods, Chuo Engineering reduced the number of times they needed to perform topology optimization analysis of existing metal parts by 93%. In addition, it reduced weight by 54%, which was the objective of the topology optimization analysis. Chuo Engineering believes introducing this machine-learning-based process has solved the problem of topology optimization and increased its value.

Conclusion/The Future

Topology optimization using machine learning is currently underway at Chuo Engineering, not only for lightweight analysis, but also for multi-disciplinary applications such as lightweighting and rigidity verification. Their engineering team is also working on the GUI of the “AI Automatic Execution Tool,” a solution currently under development to make it more user-friendly, and a tool that will expand the approach of applying machine learning to analyses other than topology optimization, such as structural, thermo-fluid, and electromagnetic analysis.



TOP: Comparison between initial optimization results and final design, resulting in a 54% weight saving compared to the existing part.
BOTTOM: A simulation time saving up to 93% has been achieved with the new AI-driven optimization workflow.