PRECISION ADM
ADVANCED DIGITAL MANUFACTURING

Titanium Topology Optimized "TiTO™" 3D Printed Satellite Panel Support System

White Paper

By Precision ADM

Abstract

Precision ADM developed a "TiTO™" (Titanium Topology Optimized) Aerospace Panel Support Structure. The purpose of the project was to use topology optimization to redesign and replace a machined aluminum mount for supporting loads from a large panel and its cable management. The goal was to optimize the structural geometry to be light-weight, while maximizing its stiffness using a material that has a low coefficient of thermal expansion. Design for Additive Manufacturing (DFAM) principles were applied so the resulting design configuration could be built using Direct Metal Laser Sintering (DMLS) with minimal post-processing or machining.

DFAM LEVEL L1 L2 L3 L4

The **Advanced Digital Manufacturing™** Company

Introduction

Topology Optimization (TO) is a computational method or mathematical approach that optimizes a material within a given design domain or space, for a given set of loading and boundary conditions such that the resulting layout meets a desired set of characteristics. (Wikipedia).

Using topology optimization, Designers and Engineers push conceptual designs to meet and exceed the predefined design requirements. Topology optimization typically increases shape complexity to resemble “Organic-like” structures. The results are used to inspire a conceptual design that is then fine-tuned for aesthetics, function and overall performance. This design process can replace time consuming and costly design-prototype iterations and hence reduces overall design development time and cost, while improving the final product.

Purpose

The purpose of the project was to use topology optimization to redesign a machined aluminum mount into an optimized light-weight structural geometry with a material that is light and stiff, but also offers a low Coefficient of Thermal expansion. The product needs to be capable of supporting loads from a panel and its cable management, and also be manufactured by Direct Metal Laser Sintering (DMLS) with minimal post-machining to keep manufacturing costs down.

Method

The original panel support structure was an aluminum mount machined from an aluminum billet weighing 1.78 kg as seen in Figure 1.

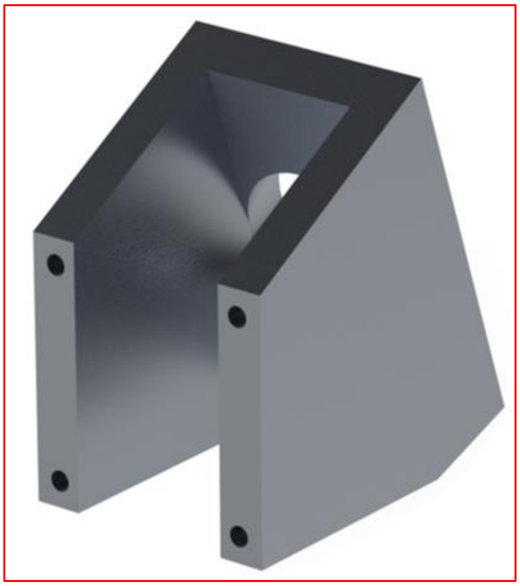

Figure 1. Original Aluminum Panel Support Structure

A series of three supports are used to support the full weight of the panel. Refer to Figure 2.

Figure 2. Mounting Pattern

Four-hole bolt patterns are used as interfaces to fasten the panel to the mount and to fix the mount itself. These locations could not be altered per the design constraints. The design also required provisions for installing of a cable gland between the mounting holes to route cables directly to the panel. The mount subassembly can be seen in Figure 3.

Figure 3. Design with Cable Glands

To minimize the geometric constraints in the topology optimization, an overall bounding volume for the design was modeled for the analysis. The eight mounting points and the cable gland interface were incorporated into the bounding volume as “non-design space,” meaning that the optimization would not attempt to remove material from these locations.

The part was fixed at the four support structure mounting locations. Loading from the panel weight was applied to the four panel mounting locations and at the cable gland interface as seen in Figure 4.

Finally, a plane of symmetry was added to control the optimized shape to ensure the results would be symmetric about the center plane.

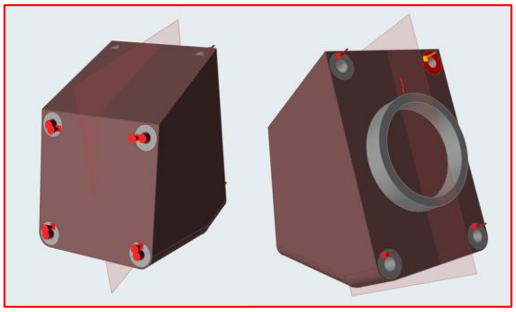

Figure 4. Topology Optimization Set-up

Topology optimization was performed with the objective of maximizing stiffness at 30% of the total design space volume. Minimum wall thickness constraints were applied as well.

Results

Using these parameters, the topology optimization process removed 70% of the overall design volume material, while leaving behind the optimum part geometry to maximize the part stiffness for the remaining volume and given loading scenario. The optimized, organic-looking geometry was then used as a concept for final design geometry determined by the engineer. The final part geometry was designed in CAD software. The topology optimization results and the final design of TiTO™ are illustrated in Figure 5.A and 5.B, respectively.

Additive manufacturing using DMLS requires the use of support structures on unsupported, overhanging surfaces for part stability and heat dissipation during the process. In general, any surface at an angle less than 45 degrees relative to the build plane requires support geometry that must be removed by either breaking it away or with post-machining.

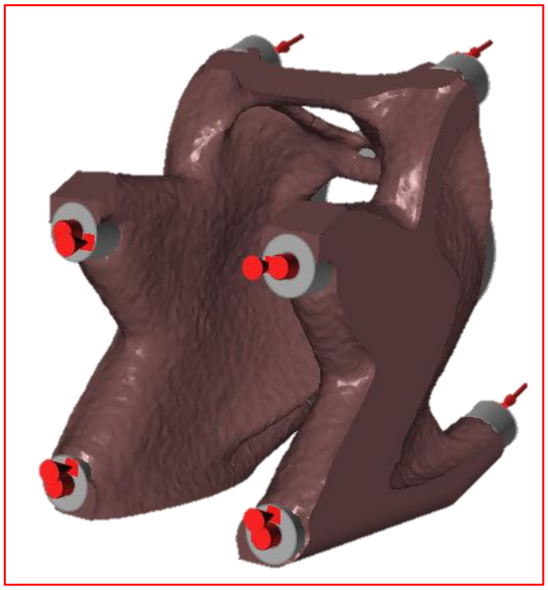

Figure 5.A

Figure 5.B

The final geometry of the TiTO™ Panel Support Structure was specifically designed with self-supporting geometry to eliminate the need for any post-machining work.

The majority of the extruded features and cutouts are self-supporting geometry as seen in the Figure 6. Only three

Figure 6 Final Design Build Orientation

small breakaway support structures were required on the entire part to complete the build.

From a modal analysis that was performed on both the original and new designs, it was found that the first resonant frequency of the new titanium design was within 2% of the original aluminum design.

Precision ADM successfully manufactured the TiTO™ Panel Support Structure using DMLS printing. The final titanium design weighs 0.69 kg, a 61% reduction in weight from the original aluminum design. The part was stressed relieved and removed from the build plate using wire EDM machining. Sand-blasting and tumbling were performed to achieve a satisfactory surface finish. All eight mounting bolt locations were tapped as the final processing step.

Conclusion

The project was successful in illustrating the potential of combining topology optimization and Design for Additive Manufacturing (DFAM) principles to develop lighter, stiffer parts that require minimal post-processing steps. It resulted in a robust design that met all requirements and allowed metal additive manufacturing processes to build in an efficient and cost-effective manner.

References

1. Svard, Hendrick 2015., *Topology Optimization of Fatigue-Constrained Structures.* Doctoral Thesis, KTH Engineering Sciences Stockholm, Sweden 2015.

DMLS Material Properties	
Properties As Built	**Ti6,4 ELI**
Ultimate tensile strength	1250 ± 50 MPa
Yield strength, Rp 0.2%	1130 ± 75 MPa
Elongation at break	9 ± 3 %

PRECISION ADM
ADVANCED DIGITAL MANUFACTURING

Headquarters:

Unit A -1595 Buffalo Place
Winnipeg, Manitoba
Canada
R3T1M1
T: +1 204.289.4491
e: info@precisionadm.com
W: www.precisionadm.com