GENERATIVE DESIGN

FRONT BRAKE PEDAL

CORNELL RESISTANCE RACING

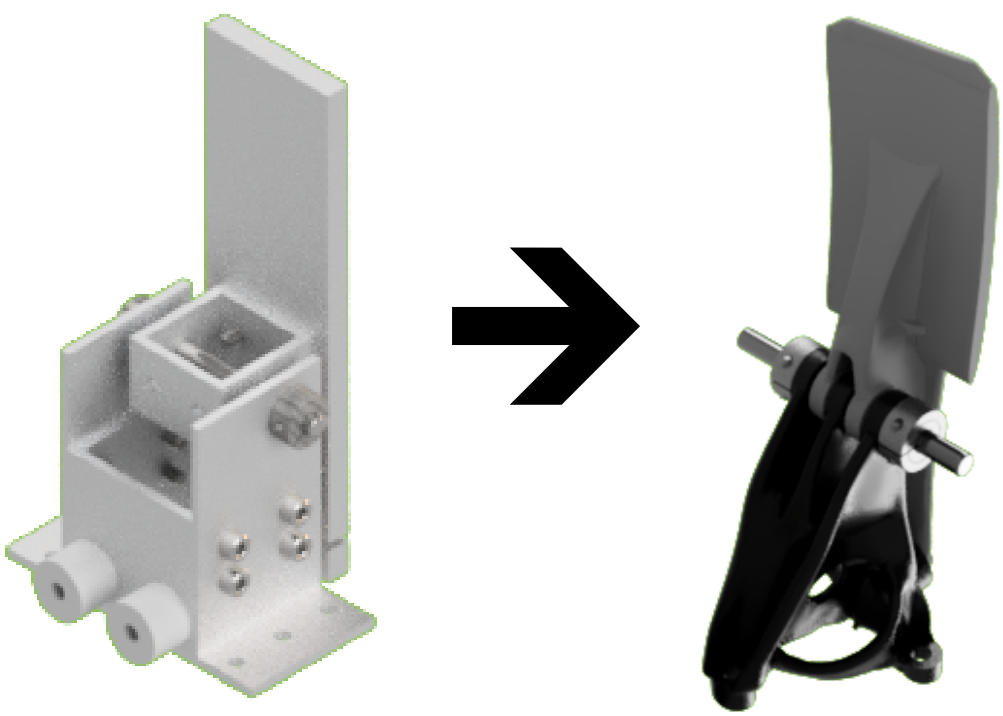
2019 SHELL ECO-MARATHON
TECHNICAL INNOVATION AWARD SUBMISSION

BENEFITS OF GENERATIVE DESIGN

Using the *Autodesk Fusion 360* Generative Design workspace, we redesigned our front brake pedal to be **optimized for mass and strength** and **designed for assembly and manufacturing**. This resulted in a design that is ***80% lighter*** and comprised of ***less than a third of the components*** of the original design.

550 g to 110 g

This significant decrease in mass reduces the tire rolling resistance, which accounts for up to 62% of the total drag force. [1] This decrease in drag ultimately results in lower energy consumption.



23 to 7 components

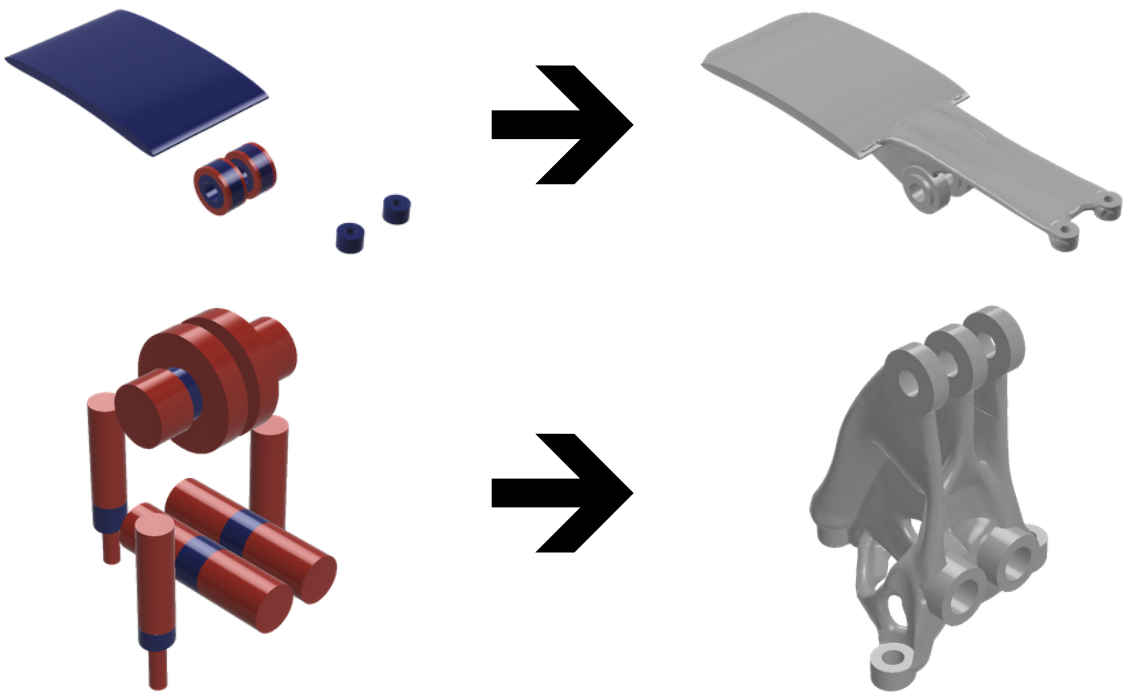
Having a subassembly with less components is beneficial, as switching out parts and re-assembling will be faster and easier.

HOW IT WORKS

Generative Design is fundamentally different from traditional CAD design. The software creates an optimized shape based on the specified part requirements.

Design Process

We first defined various design requirements.



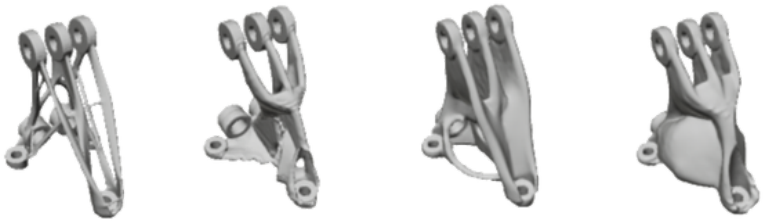
PRESERVE GEOMETRY — Defines the geometry features that must be present in the final part such as mounting holes.

OBSTACLE GEOMETRY — Defines areas in the design space that cannot interfere with the final part, such as bolt heads.

MATERIAL SELECTION — Choice of material determines the elasticity and strength properties to be used in the design.

MANUFACTURING METHOD — Design can be constrained for manufacturing with an FDM 3D printer or CNC machining (3 or 5 axis).

LOAD CASES — The attachment method and loading conditions of the part tell the software how strong it needs to be.

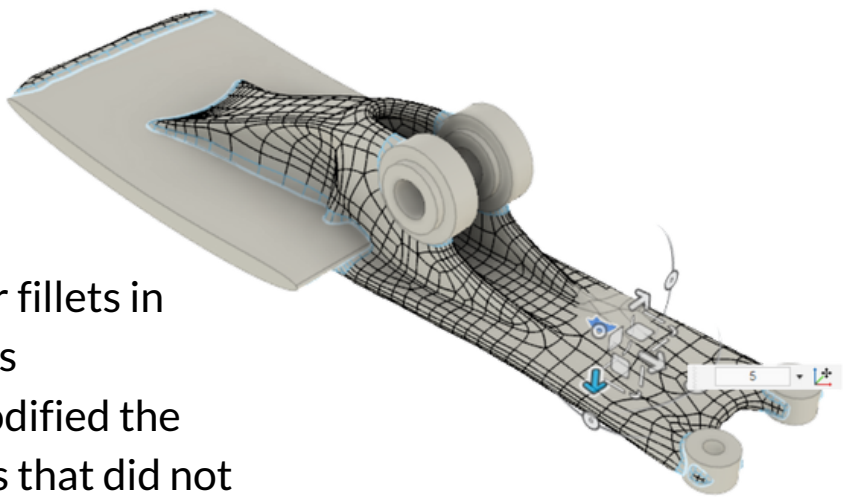


Iteration Selection

As generative design returns its full iteration cycle, we were able to analyze multiple iterations and select the output that met all of our criteria.

T-Spline Body

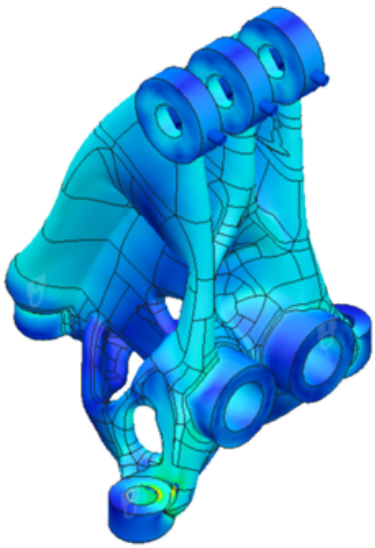
Generative design allows us to edit the part after exporting.

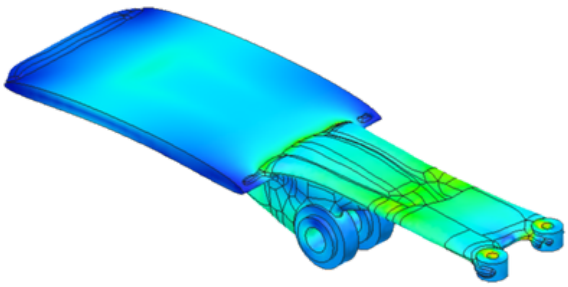


In the Organic Sculpt workspace, we modified the splines to create better fillets in some areas with high stress concentration. We also modified the splines that defined shapes that did not meet 3D printing guidelines.

Design Validation

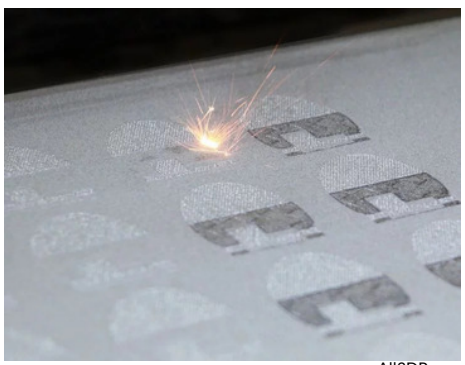
We chose to validate the design with a supplementary finite element analysis to ensure that the generated design result meets the required factor of safety.





Selective Laser Sintering

Selective laser sintering is the process of melting plastic or metal powder to itself, layer by layer, using a high power laser. We chose to use Nylon PA 2200 and Nylon PA 12 because they met the balance between cost, lead time, mechanical properties, and accessibility.

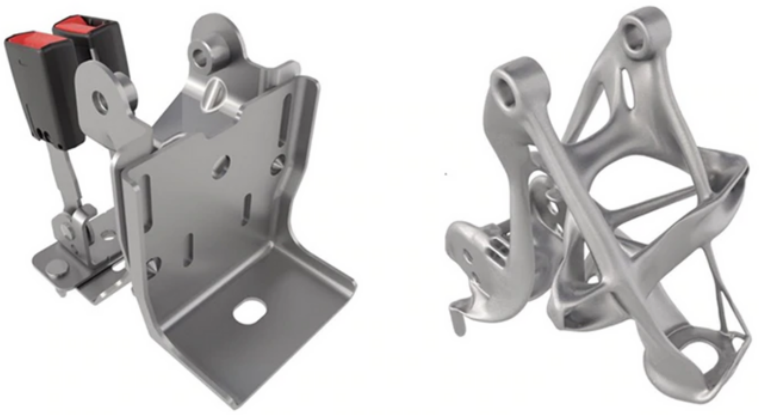


All3DP.com

Engineeringproductdesign.com

POTENTIAL FOR REAL WORLD APPLICATION

Generative design is a tool and a way of working that combines the skills of the engineer and the enormous computational power of modern computers, to output designs that would have been impossible to realize.



Autodesk.com

Generative design applies heavily to the automotive industry, where lighter components translates into increased fuel efficiency and lower costs.

Autodesk has collaborated with General Motors to develop a seatbelt bracket assembly. The generative design, which consolidated 8 components into one, is 40% lighter and 20% stronger. [2]

While additive manufacturing is currently unsuited for mass production, it reduces the barrier to entry for low volume markets such as electric vehicles. By minimizing weight, EVs are able to acheive longer ranges and faster acceleration.

Resources

[1] Santin J.J., et. al. The World's Most Fuel Efficient Vehicle. ETH Zurich. 2007
[2] Autodesk, General Motors. Driving a lighter, more efficient future of automotive part design. 2018. https://www.autodesk.com/customer-stories/general-motors-generative-design

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