Fusionlänk (VG)
https://a360.co/3cosDmG

Foto på en flasköppning (VG)

Fig 1 – Photo of one of many successful openings. Own work.

Video of an opening
https://youtu.be/t4l8tGpS9lY

Designprocess (VG)

Overview

The challenge of this task is to create a bottle opener that can be printed using PLA and still function. The goal is to use this task to become more familiar with FEA (Finite Element Analysis), Topology optimization and the design process for polymer additive manufacturing. The result is a 3d printed, topology and FEA optimized bottle opener that snap-fits onto the cheap screwdriver that ships with the Creality brand Ender 3d printers.

Idea stage

The bottle opener is a common tool that has been designed and re-designed since it’s invention over a century ago[1]. This gives us a working knowledge of the tool including a rough estimate of the stresses involved during use. This also means that there might be some interesting, expired patents to glean information from for our design (*fig 2 and 3*).

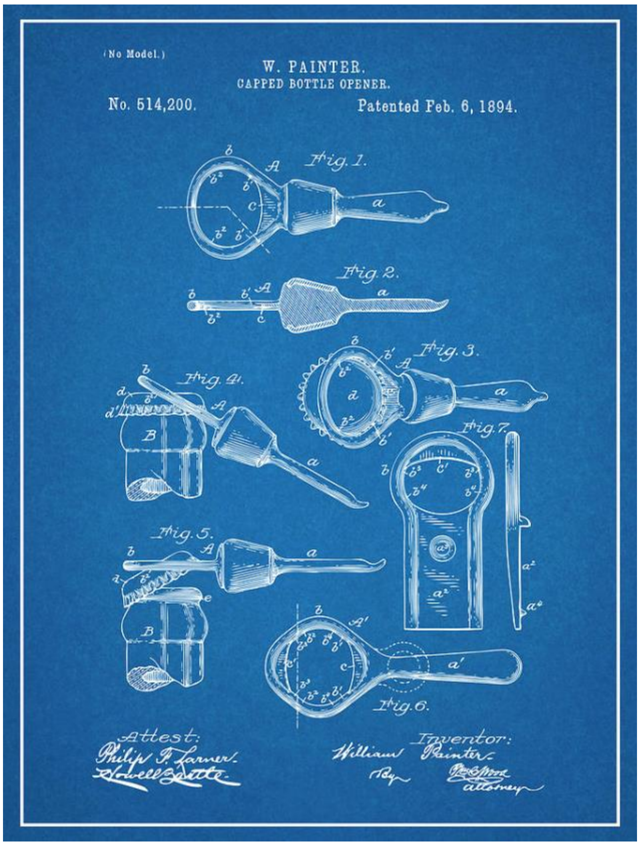

Fig 2 - Example bottle opener patent from 1894. Source: Google patent search.

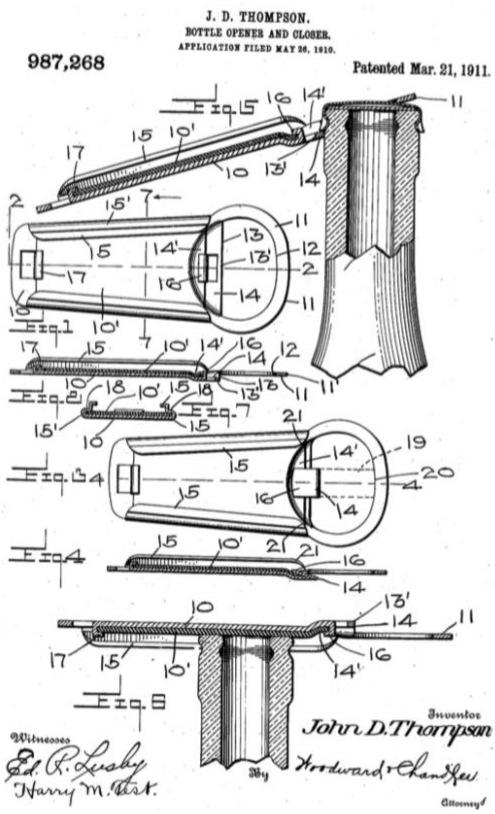

Fig 3 - another interesting, expired patent where the opener can be used to seal the bottle after openeing. Source: Google patent search.

Understand the problem

It will be important for us to understand what the shape and dimensions of bottles and caps are today. It is important for us to know how much clearance is available between the cap and bottle, and if there are different clearances on different bottles from various beverage brands. A simple test is carried out by a quick jaunt to the grocery store refrigerator to grab the various bottle types available. This may not be the best representation of the complete spectrum of bottle types, but it is good enough for our initial study *(fig 4)*.

[1] ”Crown cork” *Wikipedia,* Wikimedia Foundation, 3 June 2021, https://en.wikipedia.org/wiki/Crown_cork

Fig 4 - Four bottle shapes from different beverage companies. Note the clearance between the cap and glass is minimal on the short bottle.

We are supplied with a CAD model of a bottle cap. We can validate this model by measuring the real-world caps and compare them *(fig 5)*. We can also continue with more measurements of the bottles to understand what clearances we have to work with *(fig 6)*.

Fig 5 - Cap max width for comparison against the CAD model. Caliper raised for the photo.

Fig 6 - Series of measurements to aid in the bottle opener design process.

Rough Design - Topology optimization

We already have a good working intuition of the force load paths through a bottle opener during operation but for a visual representation, and to better understand how topology optimization works, we make some quick sketches in Fusion 360, add constraints and loads, manage the mesh resolution and run some optimizations.

These three designs *(figure 7 – 9)* were made with simple sketch and extrudes are modeled based on the size of the bottle cap and measurements from above. The style is a simple class 1 lever type.[2] Each optimization has slightly different load cases; rotational moment *(fig 7)*, remote force on a planar face *(fig 8)*, and a force on an edge *(fig 9)*.

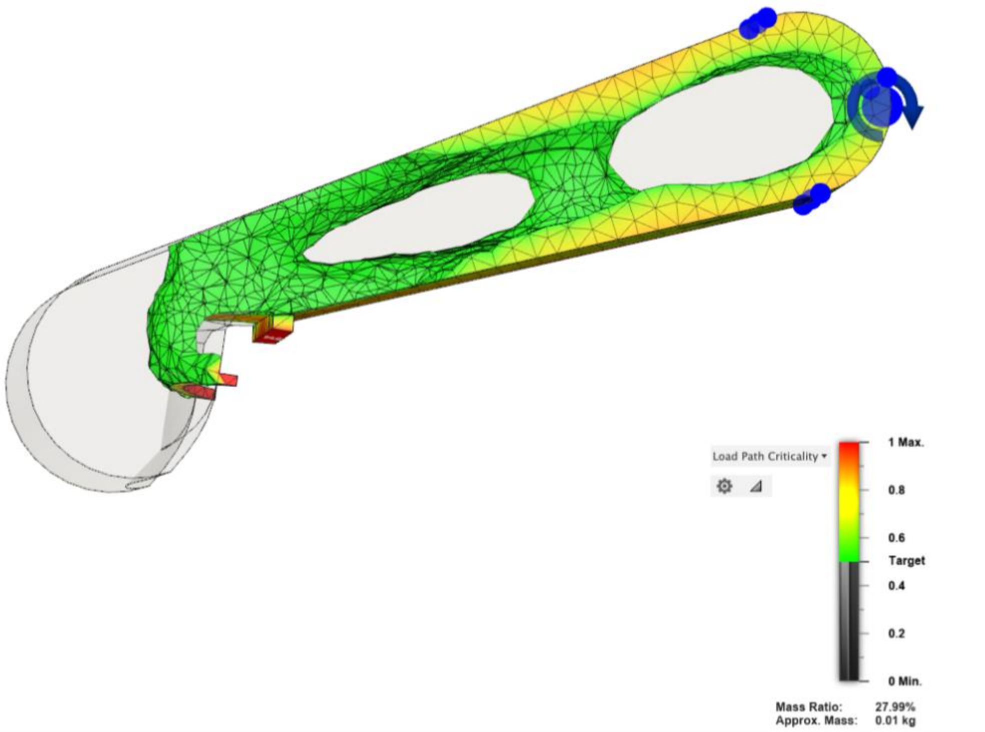

Fig 7 - Topology optimization of design A. Torque moment on arm, frictionless at fulcrum and fixed under bottle cap. Own work. Topology optimized using Fusion 360.

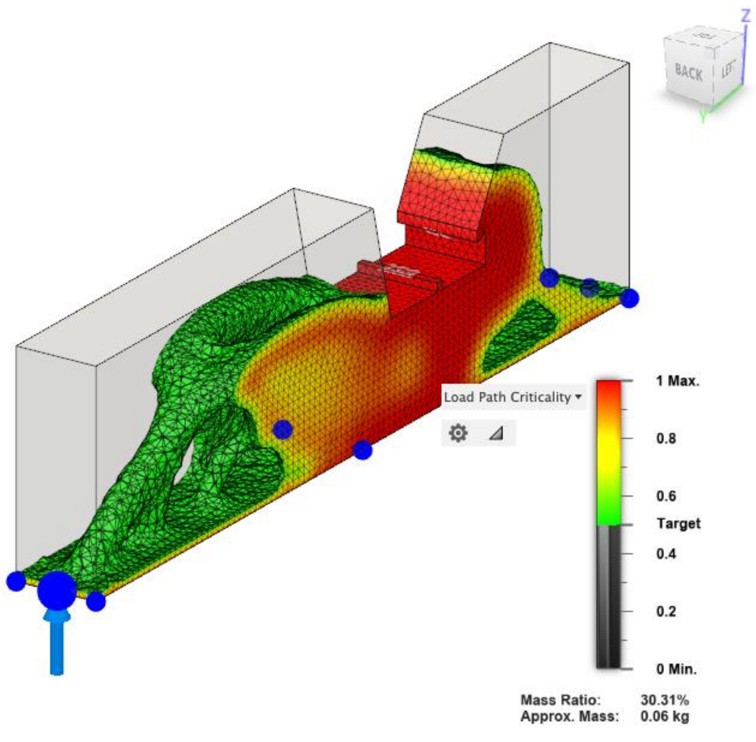

Fig 8 - Topology optimization of design B. Remote force on planar face, frictionless at fulcrum and fixed under bottle cap. Own work. Topology optimized using Fusion 360.

[2] "Lever, Classes of levers" *Wikipedia,* Wikimedia Foundation, 3 June 2021, https://en.wikipedia.org/wiki/Lever#Classes_of_levers

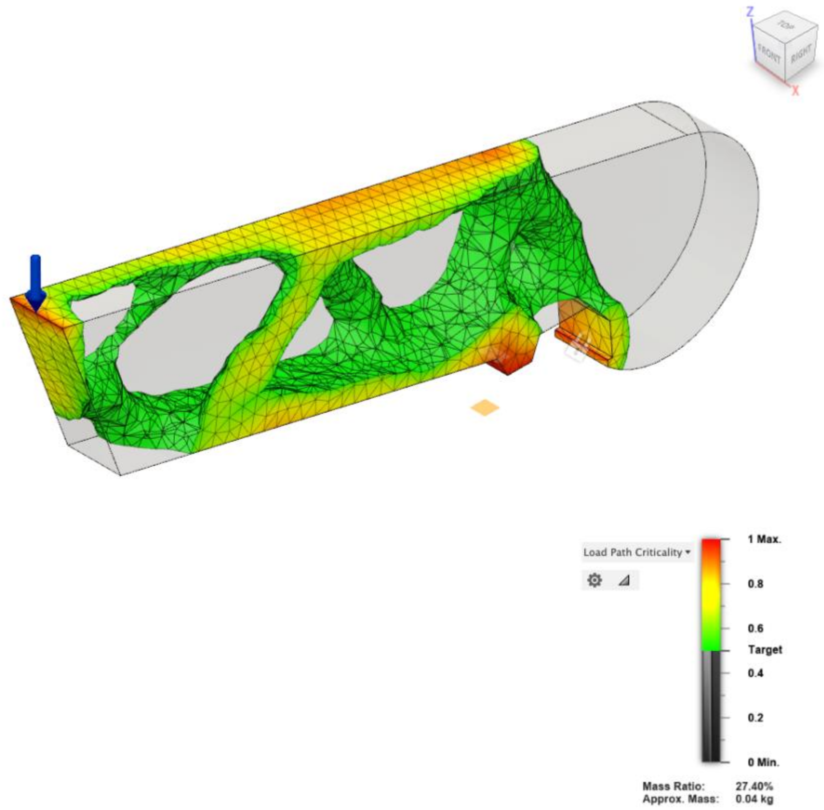

Fig 9 - Topology optimization of design C. Force on extreme edge, frictionless at fulcrum and fixed under bottle cap. Own work. Topology optimized using Fusion 360.

Issues with the above designs

Based on some common sense, we understand that there is one major flaw in the above designs. Two millimeters of PLA polymer may be enough to open one or two bottles but continued use, or even the slightest misuse of the bottle opener against the sharp and stiff steel bottle cap, will permanently damage it rendering it useless for it's designed task. Therefore, we will search for a solution to strengthen the most susceptible area under the bottle cap.

Solution

The simple solution is to insert some piece of material into the print, during or after printing, to act as a barrier between the more stiff and dense material of the cap and the PLA of the lever arm. This could be a piece of steel, a coin, washer, or in our case, a screwdriver. One of the most popular 3d printers[3], the Creality Ender 3[4], is shipped with a cheap 2.5 mm screwdriver with a steel shaft and injection molded handle *(fig 10)*. This should work nicely and be something easily replicable in case others might want to also print our design. We can quickly model up the screwdriver to use in our design.

Fig 10 - 2.5 mm screwdriver model. Own work. Rendered in Fusion 360.

The use of this screwdriver will require a class 2 lever[5] design which means a slight redesign and new topology optimization *(fig 11)*.

[3] "Amazon Best sellers, 3d printer category", retrieved on 6 June 2021, https://www.amazon.com/Best-Sellers-Industrial-Scientific-3D-Printers/zgbs/industrial/6066127011
[4] "Ender Series", 6 June 2021, https://www.creality.com/product/ender-series-3d-printer
[5] "Lever, Classes of levers" *Wikipedia,* Wikimedia Foundation, 3 June 2021, https://en.wikipedia.org/wiki/Lever#Classes_of_levers

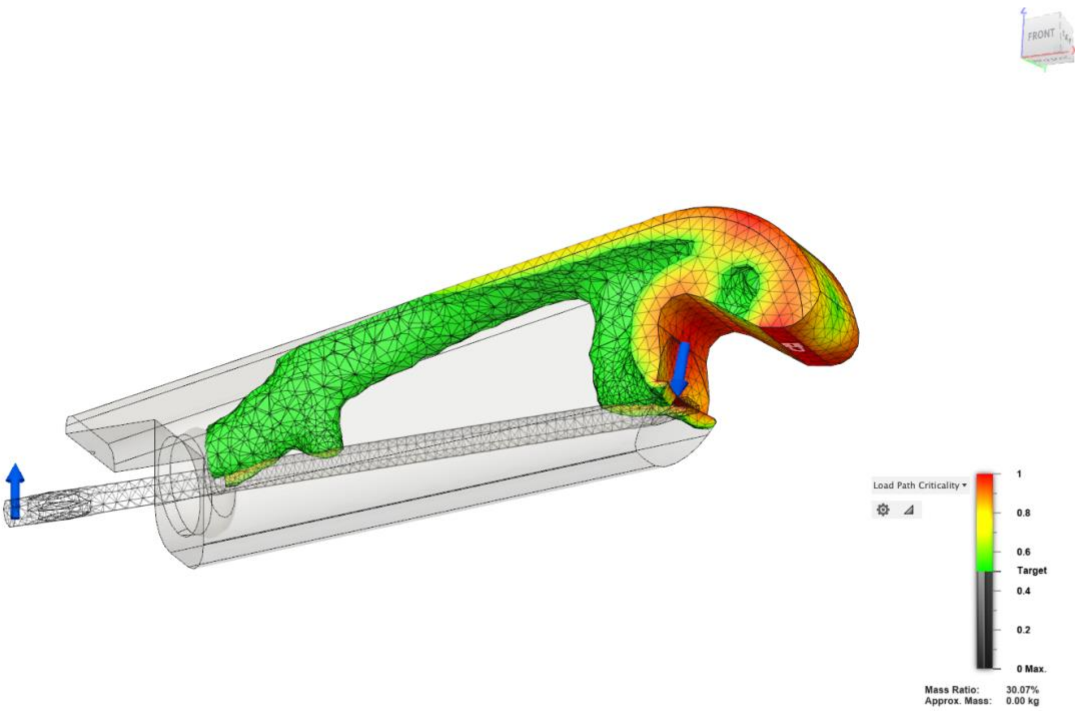

Fig 11 - Topology optimization of the bottle opener as a class 2 lever. Frictionless constraints are added between the screwdriver shaft and opener. Own work. Topology optimized in Fusion 360.

Printable CAD model

The topology optimization produces a result that can be 3d printed but we have some adjustments to make. Furthermore, we also need to consider printability of the part via FFF. Here we can practice sculpting with the t-spline form function built into Fusion 360. The result is an editable CAD model which we can save as an STL for printing. *(fig 12)*

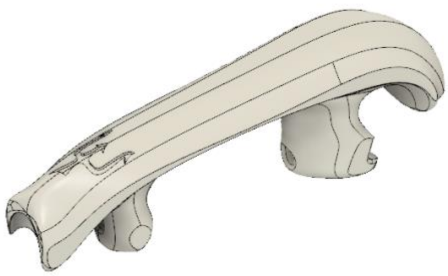

Fig 12 - Form complete and ready to be saved as an STL. Own work. Screenshot from the design workspace in Fusion 360.

Print and test

This design prints well and functions to open bottles. *(fig 13)* I am unsatisfied with the results, however. The opener deforms slightly under certain load conditions which results in the screwdriver sliding out from under the bottlecap, leaving the bottlecap forces resting on the polymer lip instead of the tip of the metal screwdriver shaft. This quickly damages the PLA which I have deemed unacceptable for my design.

Fig 13 - First print test reveals a flaw on some harder-to-open caps. Own work. Photo of first version of opener in use.

Design tweaks

A lower strut is added, bridging the gap between the screwdriver handle and the cap. This strut will prevent the elongation of the distance between the handle and the cap during leveraging heavy loads. A static stress analysis is run to ensure ample margins *(fig 14)* and the design is sent off to the printer.

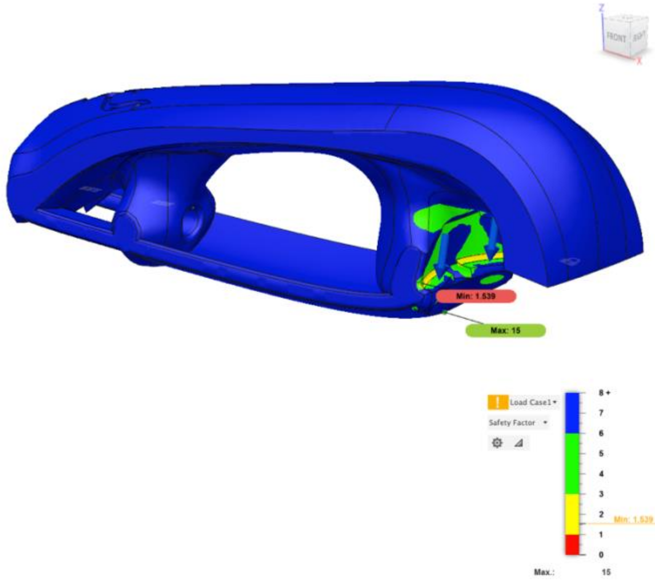

Fig 14 - Static stress analysis of the final bottle opener design shows acceptable results. Own work. Image captured from the static stress simulation workspace in Fusion 360.

Final Printing

It is worth mentioning the print orientation and settings here. Because of the isotropic nature of layer-based PLA printing, the opener is printed with one side to the print bed *(fig 15).* I have chosen five walls with twenty percent connected infill lines and 0.16 mm layer height for highest strength. Based on testing, CNC Kitchen has found layer heights below 0.2 mm to be the strongest when printing with a 0.4 mm nozzle[6]. This is good for us since a 0.16 mm layer height should yield a good surface appearance as well as higher strength than larger layer heights.

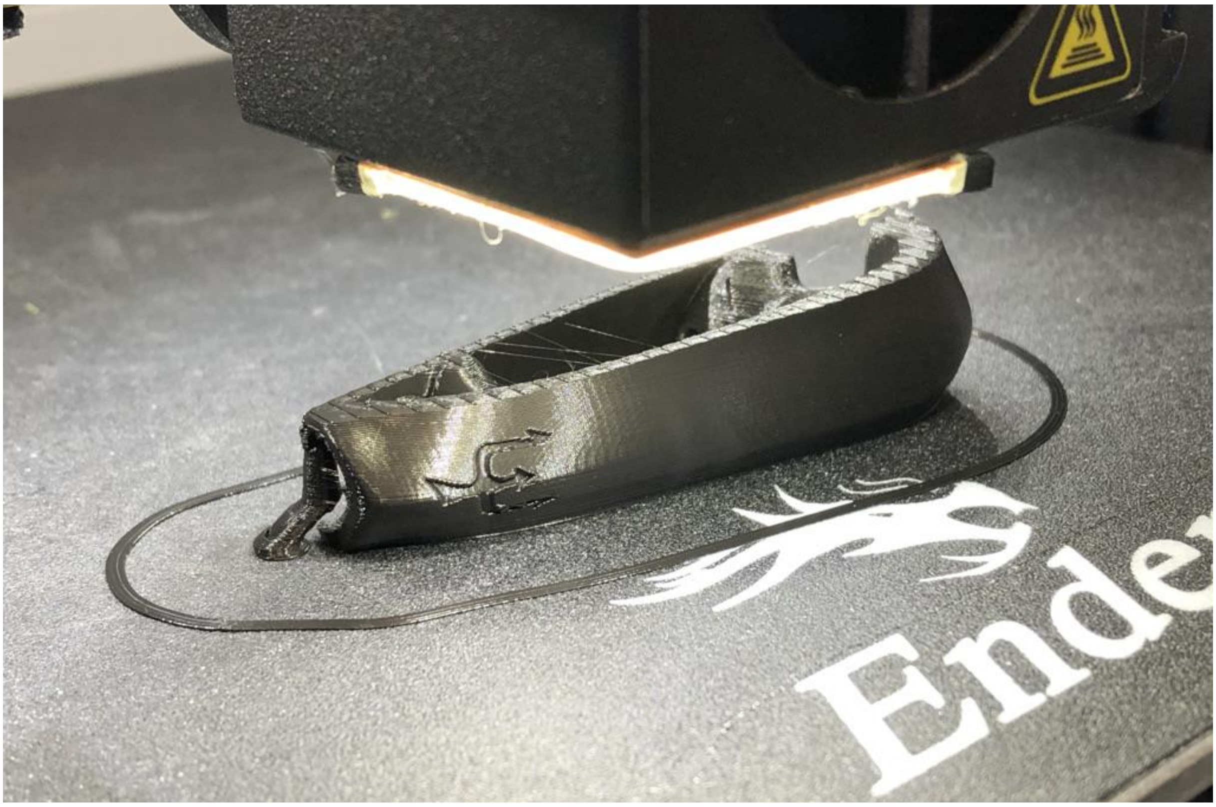

Fig 15 - Finished print of final design printed in Add-north Black E-PLA on a Creality Ender 3. Note, no support is required for this print, however, a small tree support on the left most overhang yields the best result. Own work.

[6] "The influence of layer height on the strength of FDM 3d prints", CNC kitchen, 28 September 2019, https://www.cnckitchen.com/blog/the-influence-of-layer-height-on-the-strength-of-fdm-3d-prints

Final test

The screwdriver handle has a very satisfying *click* as it snaps into place in the opener.

Fig 16 - Opener in its final form, snapped onto the screwdriver. Own work.

Fig 17 - Close up views of final design. Left, note screwdriver tip protruding slightly to reduce wear from the bottle cap on the opener. Right, the end of the opener deforms slightly as the screwdriver handle snaps into place. Own work.