PortaBottle

More Water, Whenever You Need It

Brenden Koo | ME 127 | Winter 2023

Prompt Interpretation

The prompt is fairly open-ended, and I initially opted for the route of **redesigning a part by leveraging AM capabilities**. I wanted to utilize shape optimization simulations to redesign bike-mounted water bottle holders. Simultaneously, my biggest qualm with bike-mounted water bottle holders is that those on the market (and currently mounted on my bicycle) are typically fixed for a specific size. I wanted to design a water bottle holder that is adjustable or accommodates a wide range of sizes.

Mechanical Function

The core function of my design is pretty simple–to allow people who bike to carry their water bottles with them as they go. Specifically, my design would be catered to **bikers who opt for larger water bottles** than the “standard size” single-use disposable bottles.

I'mma buy you a drank
Then I’mma take you home with me

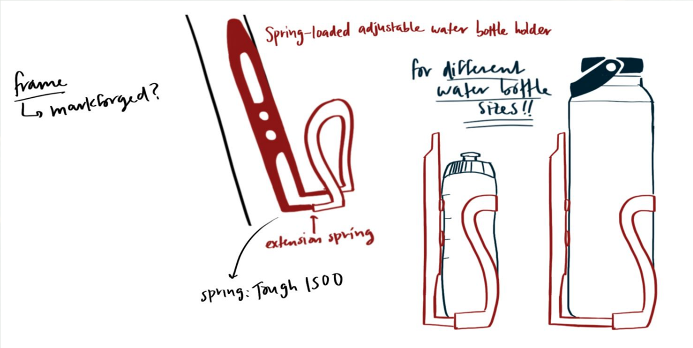
T-Pain

1.
Ideation

Initial Sketches and Brainstorms

Initial Sketches

My initial idea was a **hybrid** between an adjustable water bottle holder and something designed with algorithmic modeling



I realized that ultimately, it would be difficult to design something that is both adjustable and algorithmically modeled **within the scope of the project**. I understood that I could separate the design into parts and tackle each part differently, but in the interest of time, I opted to solve each problem separately and choose a model to pursue before I printed.

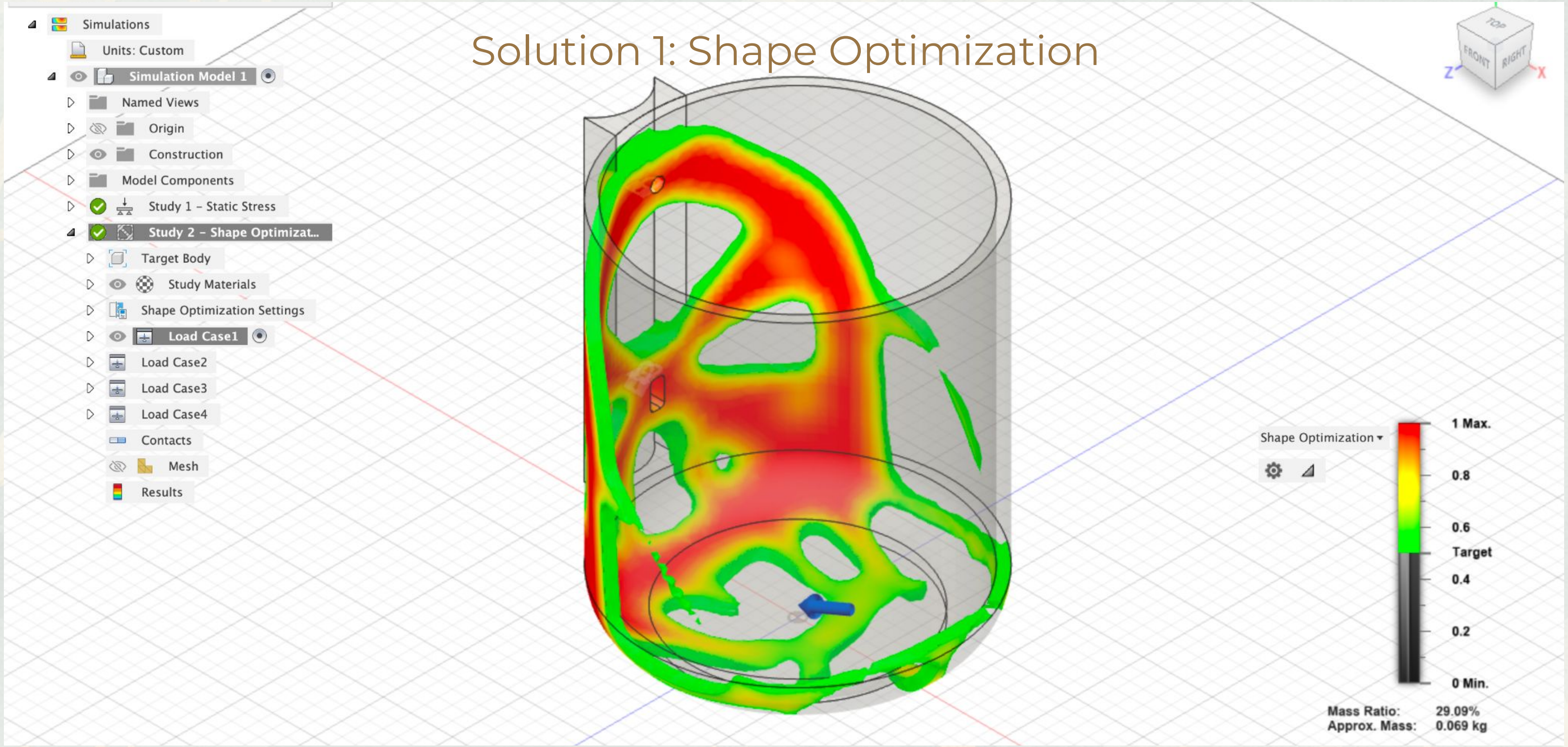
Solution 1: Shape Optimization

Solution 1: Shape Optimization

I created a model of a cylindrical shell with the same diameter of my water bottle. I constrained each of the load cases with fixed connections at the holes and applied the following load cases:

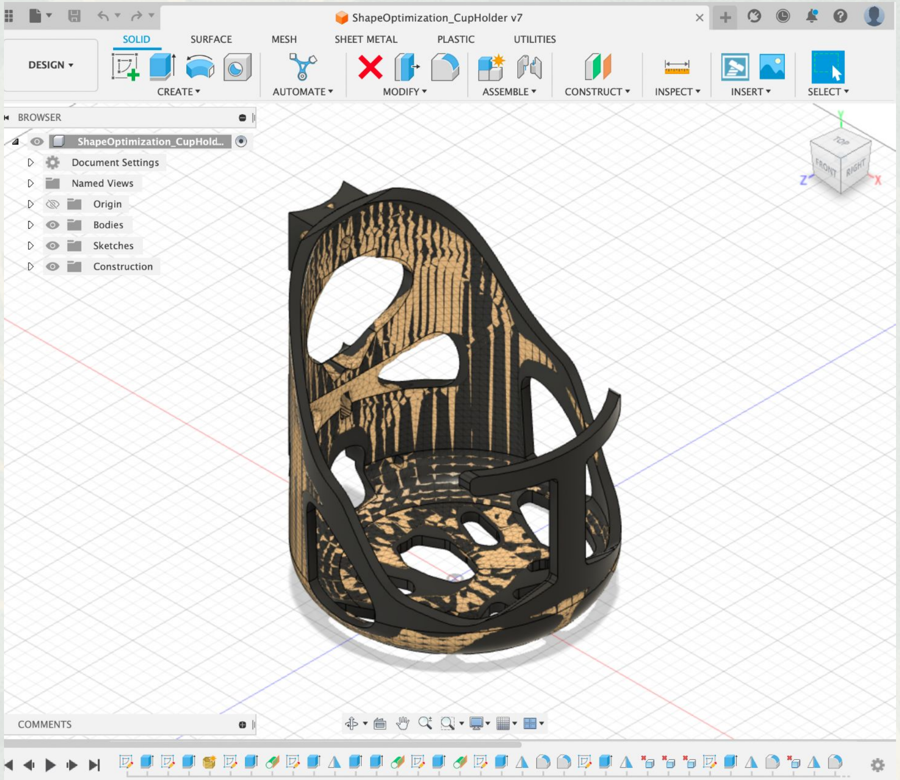
- 33.362 N load acting on the base face at a 37 degree angle
- 33.362 N load acting on the base face at a 37 degree angle and 5 N load acting normal to the cylindrical walls
- Misuse Case: 33.362 N load acting on the base face at a 37 degree angle and 5 N load acting down on the cylindrical rim
- 5 Nm moment acting on the upper cylindrical hole

Solution 1: Shape Optimization



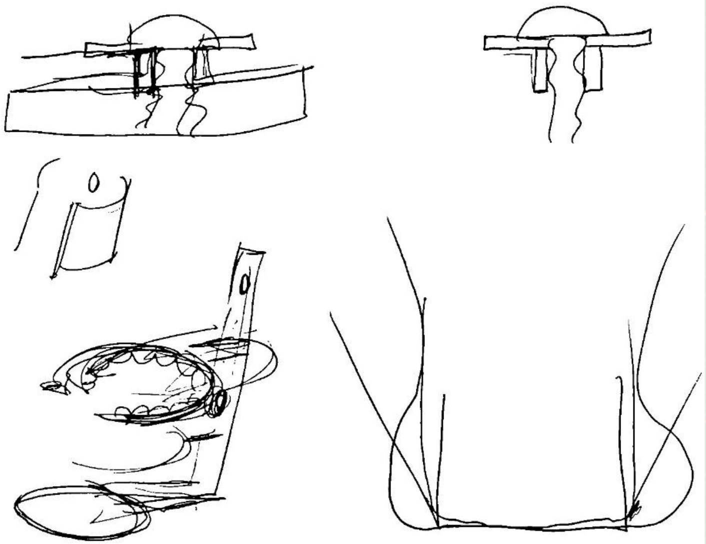
Solution 1: Shape Optimization

- The shape optimization simulation yielded the following result, which I promoted to the design workspace
- I cut-extruded the model to resemble the general model created by the simulation

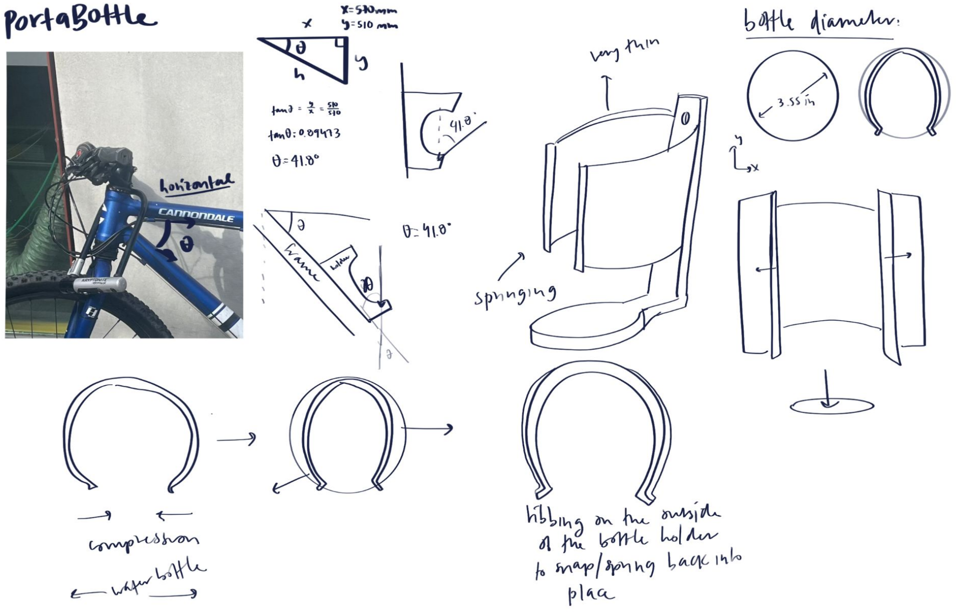


Solution 2: Adjustable Design

- After talking extensively with Dan, he suggested that I create a design that focuses on one of my goals–the one that resonates the most with me.
- I opt to pursue a design that accommodates larger water bottles, using a spring-loaded mechanism.



Solution 2: Adjustable Design



Dan showed me designs he had previously iterated for a vinyl roll clamp, which utilized a smaller, circular design that expands to accommodate the roll as it shrinks or grows.

Choosing my Solution + Revisiting the Prompt

At this point, I knew that I wanted to pursue the design that accommodates varying water bottle sizes, including the 32oz water bottles I typically drink from.

Re-thinking over the prompt, I am still trying to **take advantage of the additive manufacturing capabilities**, gaining more hands-on experience with AM and exploring material properties as it relates to flexibility and springiness.

2.

Iteration

Developing the Idea to Perfection

Material Selection

In choosing a material with flexibility and durability, I was torn between Durable and Tough 1500.

Durable Pros:

- Higher Pliability

Tough 1500 Pros:

- Faster Springback

I deduced that Tough 1500 and Durable were similar enough in pliability (the design need not be so flexible, just enough to deform slightly) but Tough 1500 had a faster springback to clamp around the bottle, which is a significant feature I wanted to implement

Material Selection – Tough 1500

Using Tough 1500, I knew that I needed to be able to have a design that would flex and bend repeatedly, all while being durable enough to hold my water bottle in place

In order to use Tough 1500 in my CAD (as the material is unavailable as a pre-set) I selected and edited Tough 2000 (in the same material family) and edited certain material properties with Tough 1500 specifications.

Initial Test Prototypes

My initial goal of my test prototypes were to finalize the proper design that could not only flex enough to fit a 32oz water bottle (with an approximate diameter of 3.55 inches) and yet springback to constrain the bottle

Initial Test Prototypes

The designs on the **left** are based on an expanded diameter of **3.5 inches** (slightly smaller than that of the bottle)

The design on the **right** is based on an expanded diameter of around **2.5 inches**

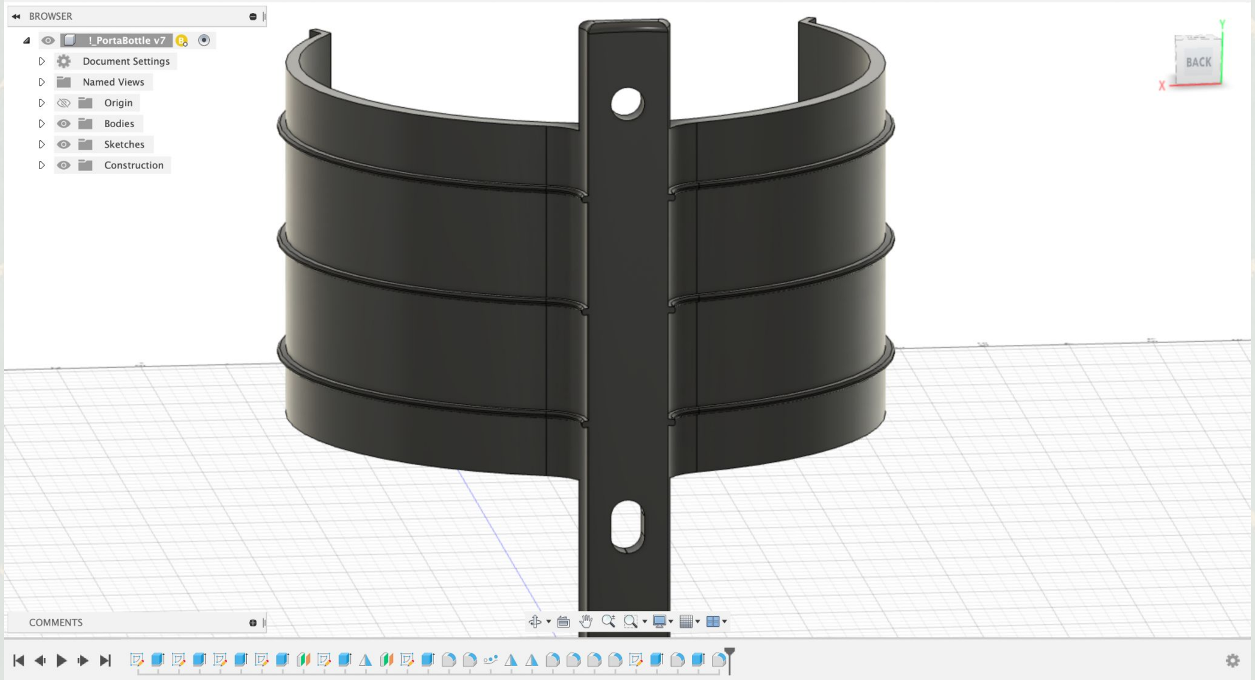
Initial Test Prototypes

The designs on the **left** were the perfect fit! They initially seemed like not the perfect fit because I removed the supports before the wash and cure, which distorted the model

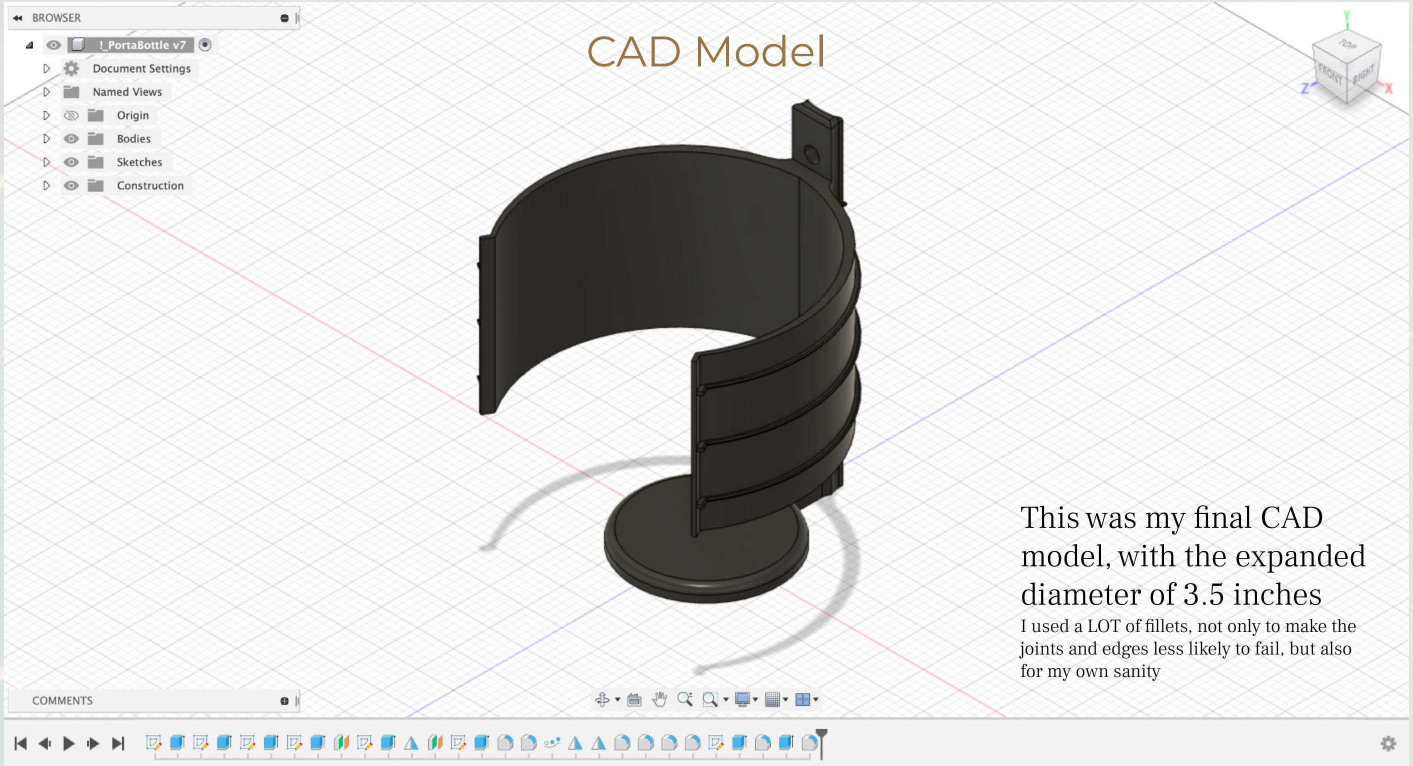
The design on the **right**, as you can see, is too small and struggles to actually clamp onto the bottle and has an unattractive empty space

CAD Models

I spaced the two holes that would constrain the bottle holder to the bike frame via the pre-made holes in my bike frame



CAD Model



This was my final CAD model, with the expanded diameter of 3.5 inches

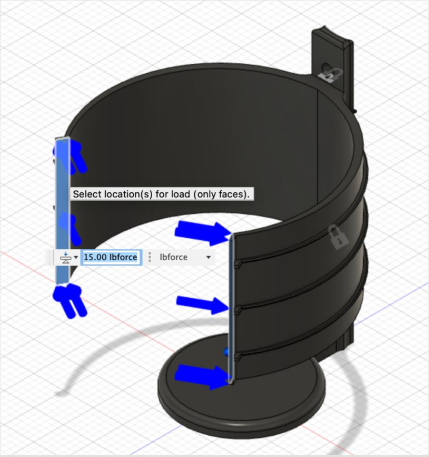
I used a LOT of fillets, not only to make the joints and edges less likely to fail, but also for my own sanity

CAD Simulations

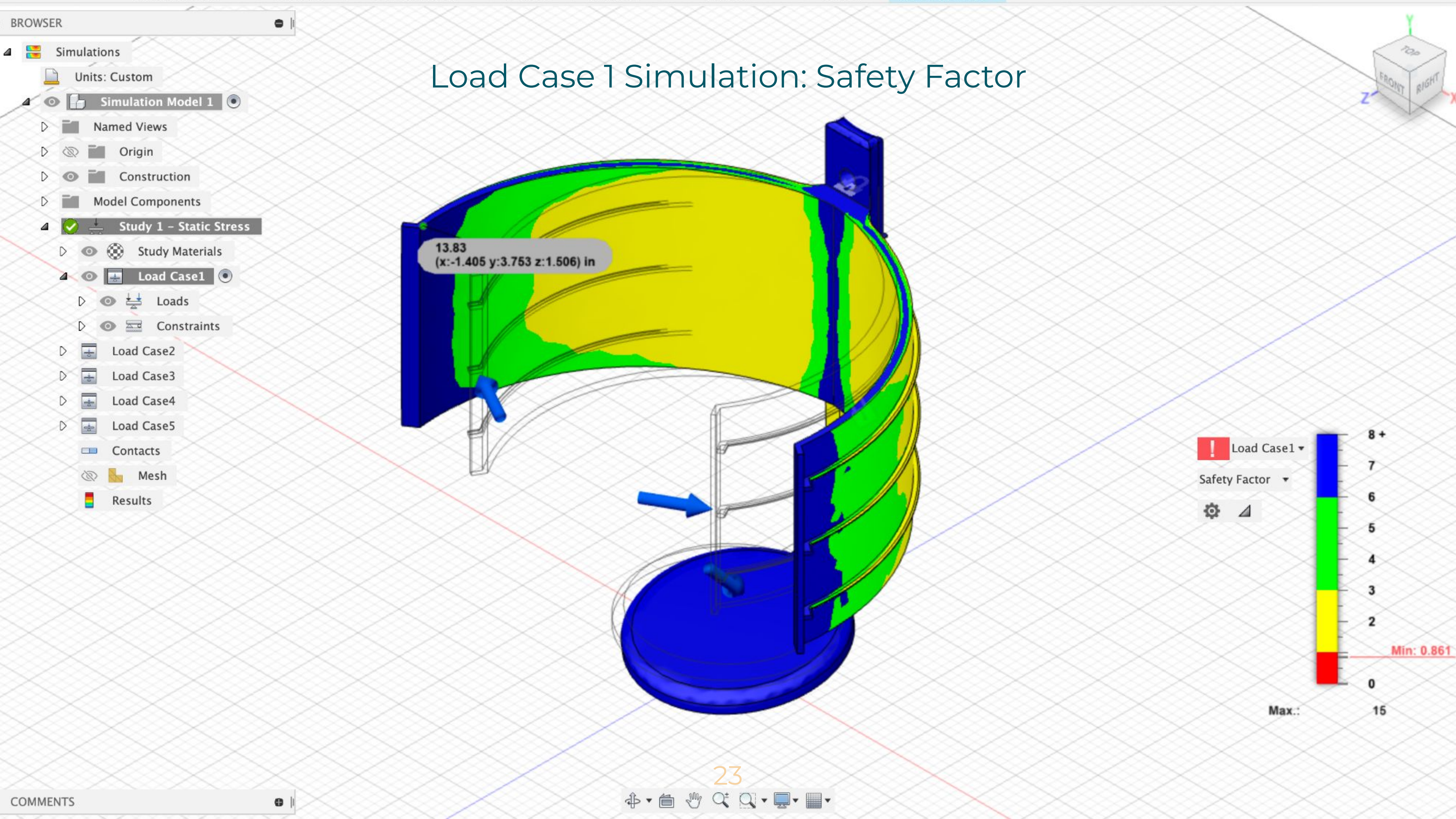
The CAD simulations implemented the following load cases (in addition to being constrained at the holes):

- Load Case 1: 15 lb-force loads acting on the outer lips and a 3.5 lb-force load acting on the top face of base
- Load Case 2: Misuse case: 15 lb-force load acting on the upper rim and a 3.5 lb-force load acting on the base
- Load Case 3: Misuse case: 3 lb-force load acting on the bottom face of the base
- Load Case 4: Misuse case: 5 lb-force loads acting normal to the external faces of the holder
- Load Case 5: 10 Nm moment acting on the cylindrical hole

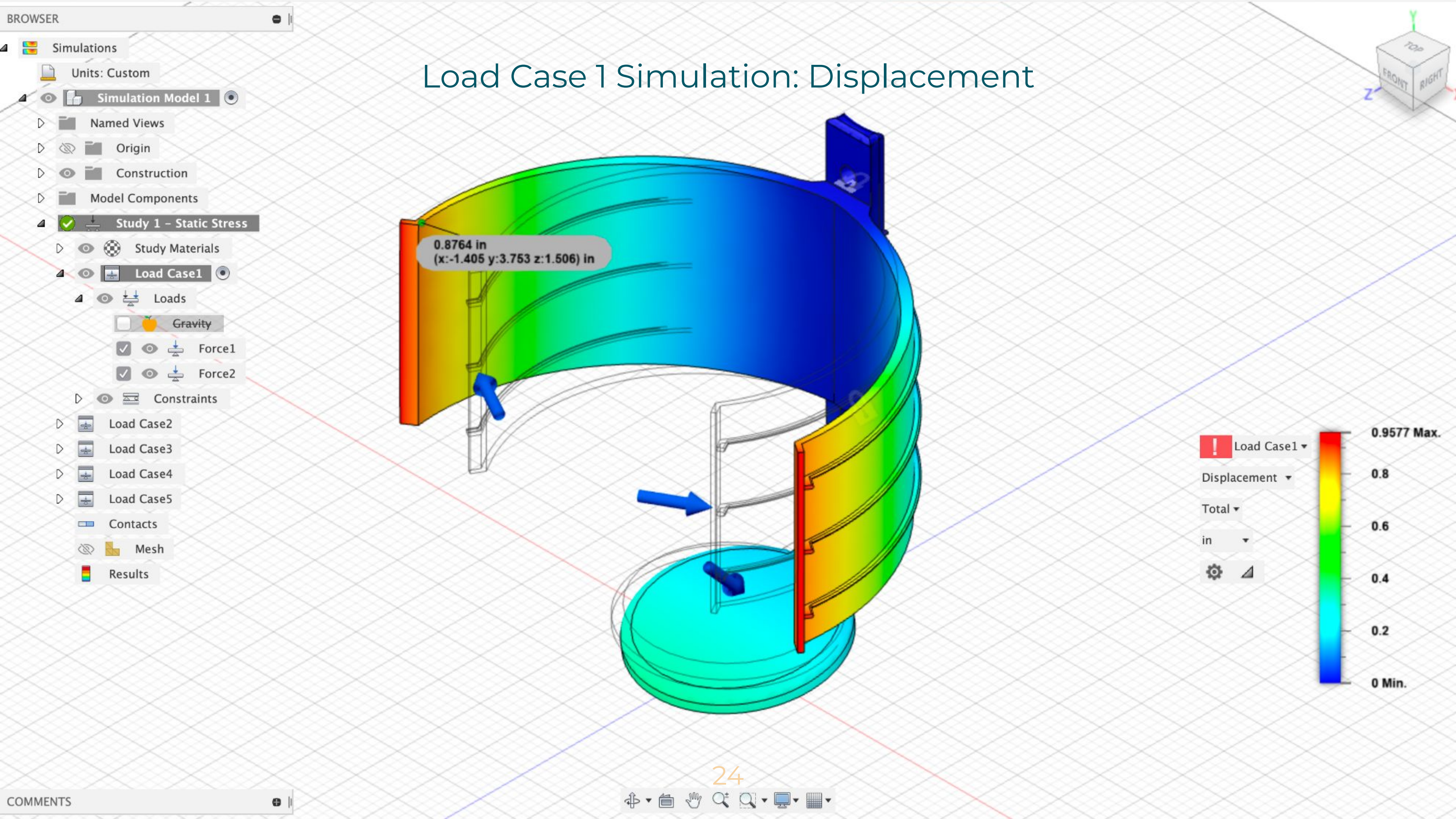
Load Case 1



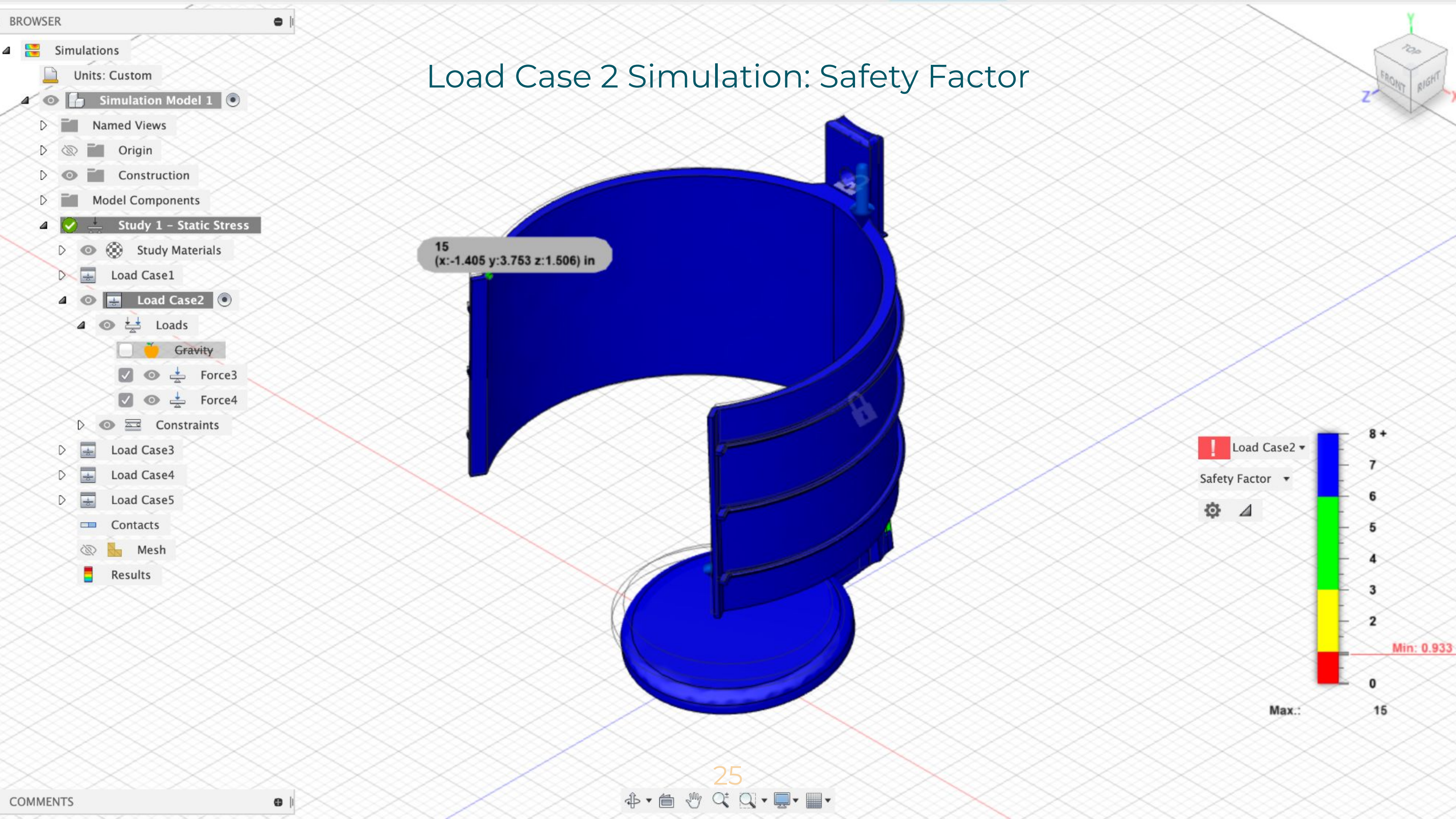
Load Case 1 Simulation: Safety Factor



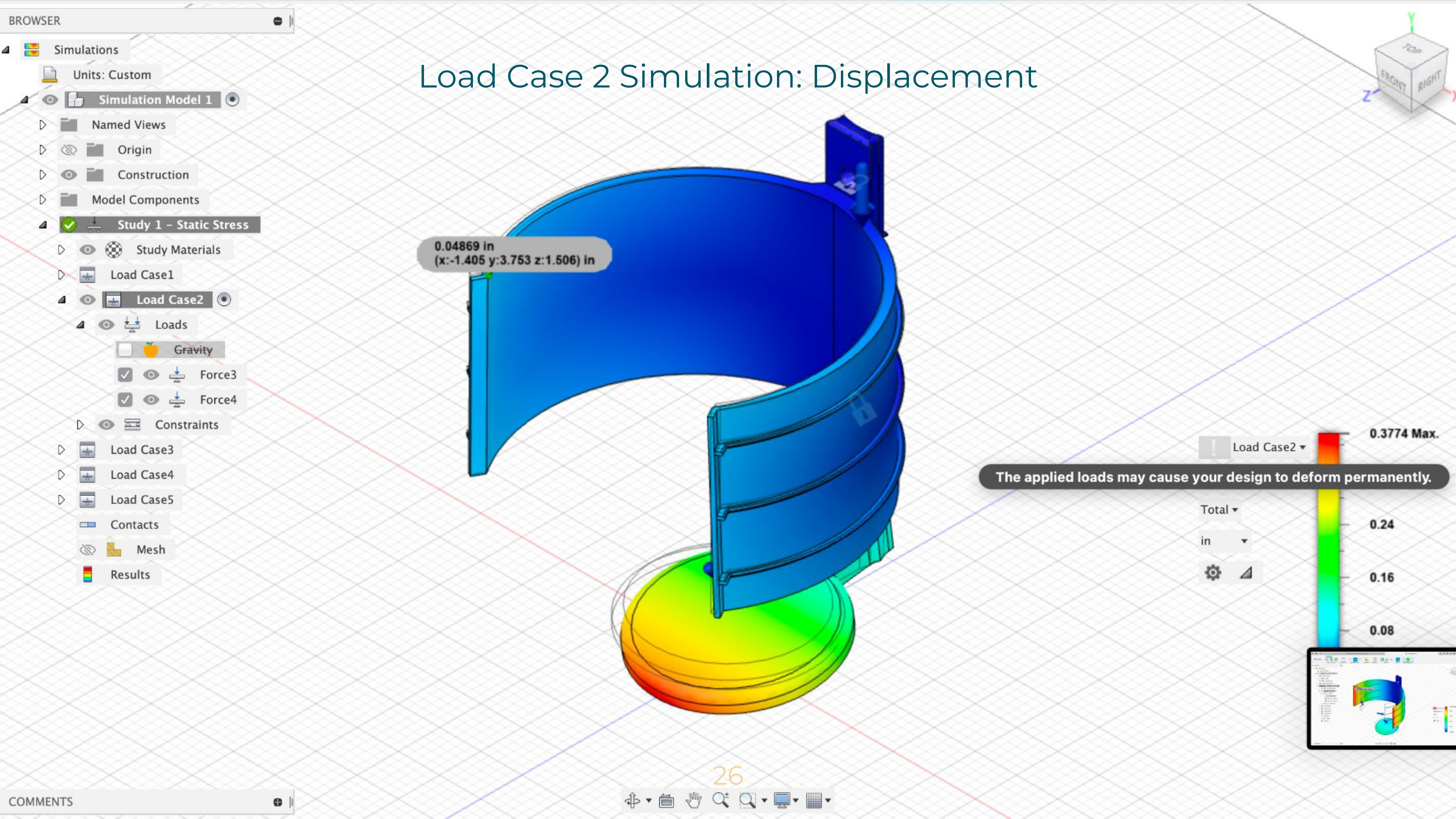
Load Case 1 Simulation: Displacement



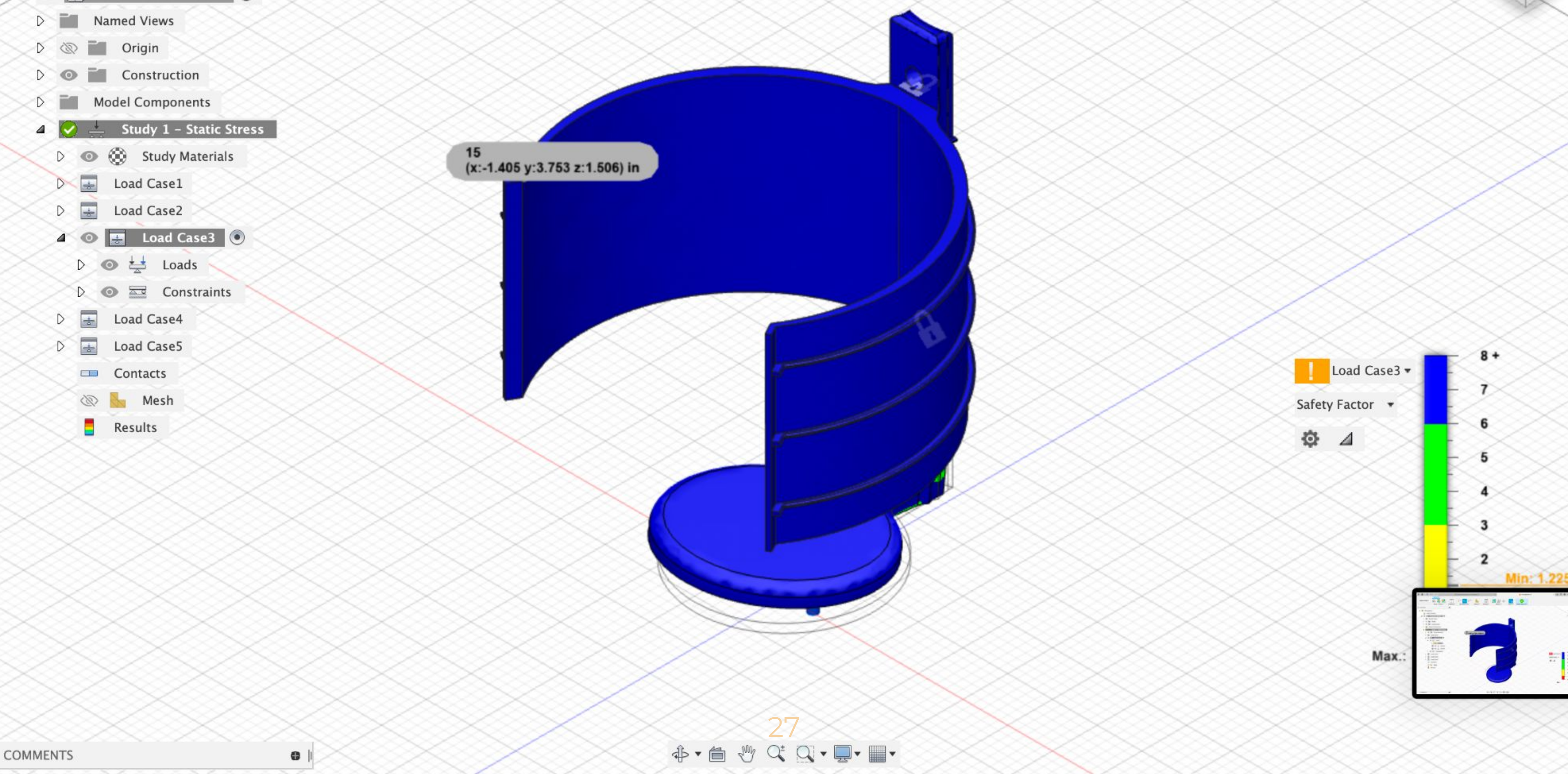
Load Case 2 Simulation: Safety Factor



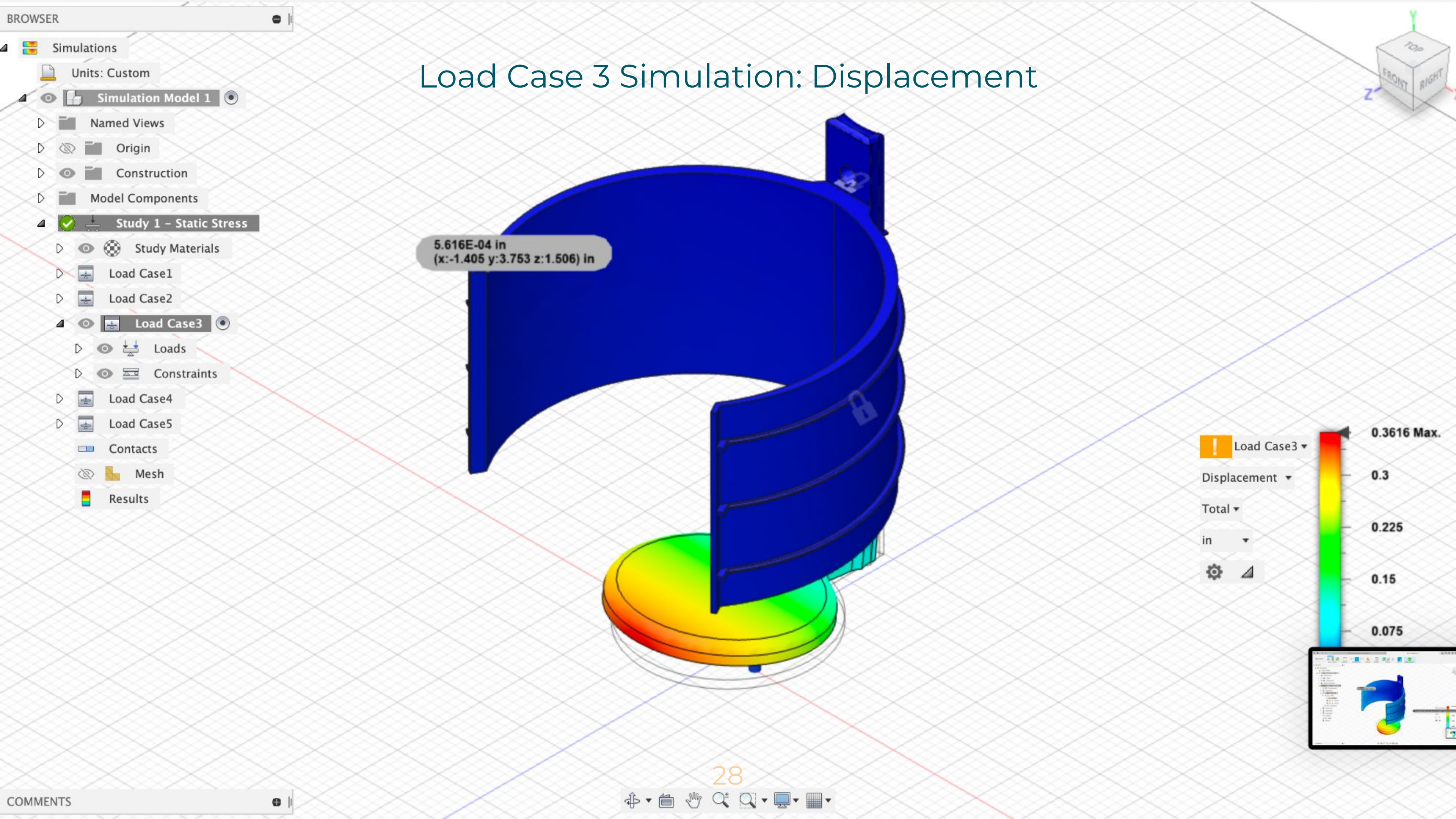
Load Case 2 Simulation: Displacement



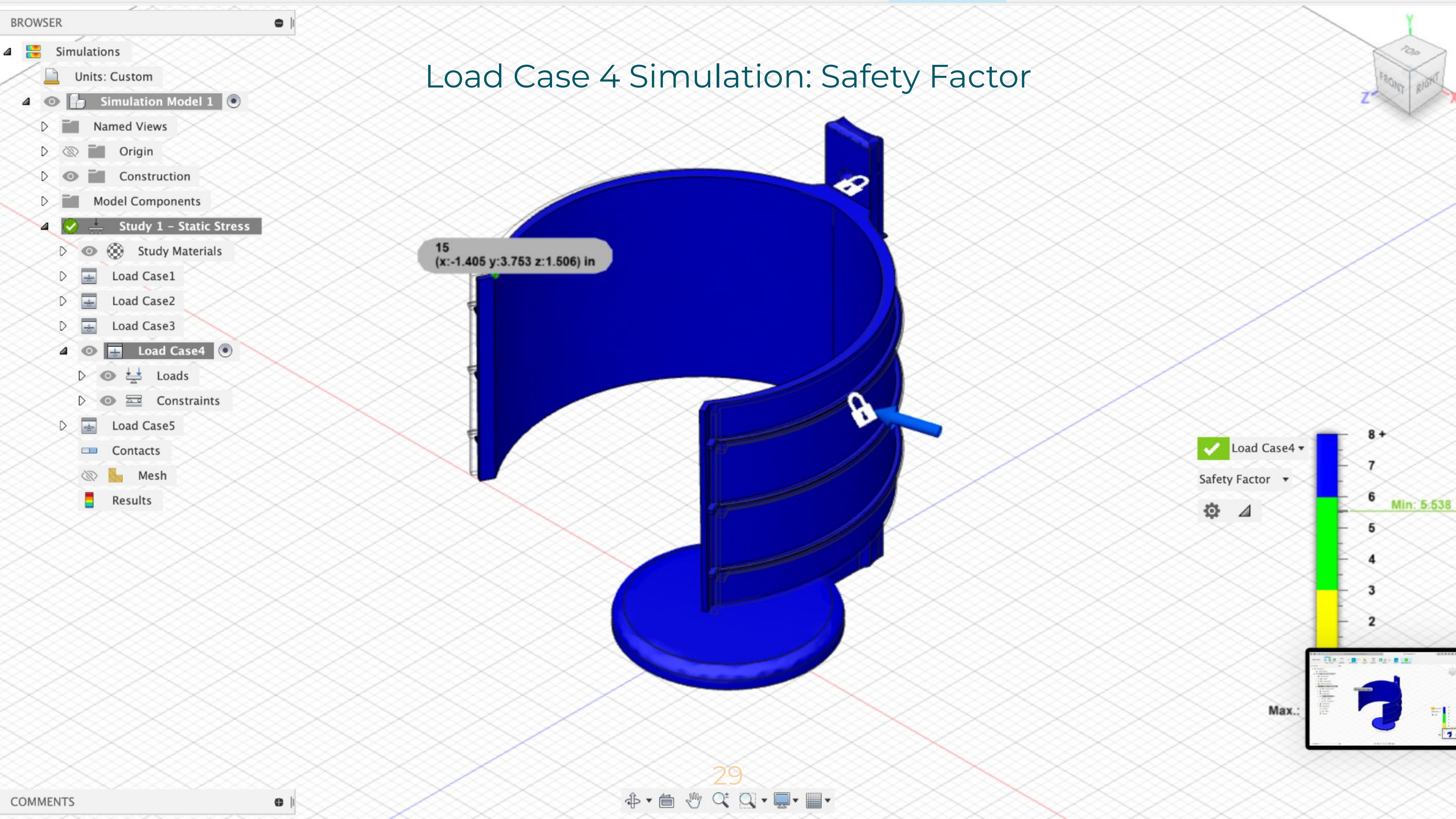
Load Case 4 Simulation: Safety Factor



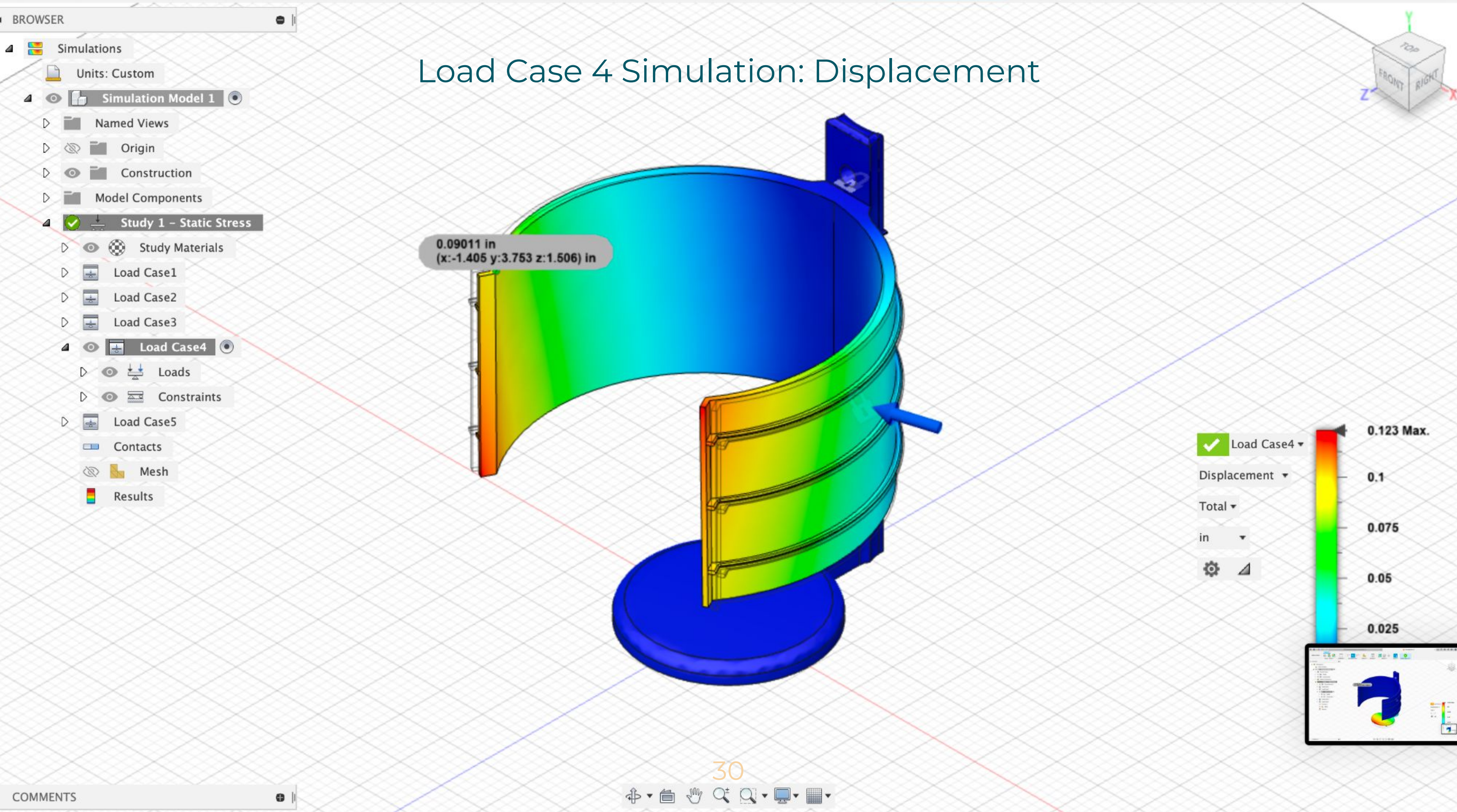
Load Case 3 Simulation: Displacement



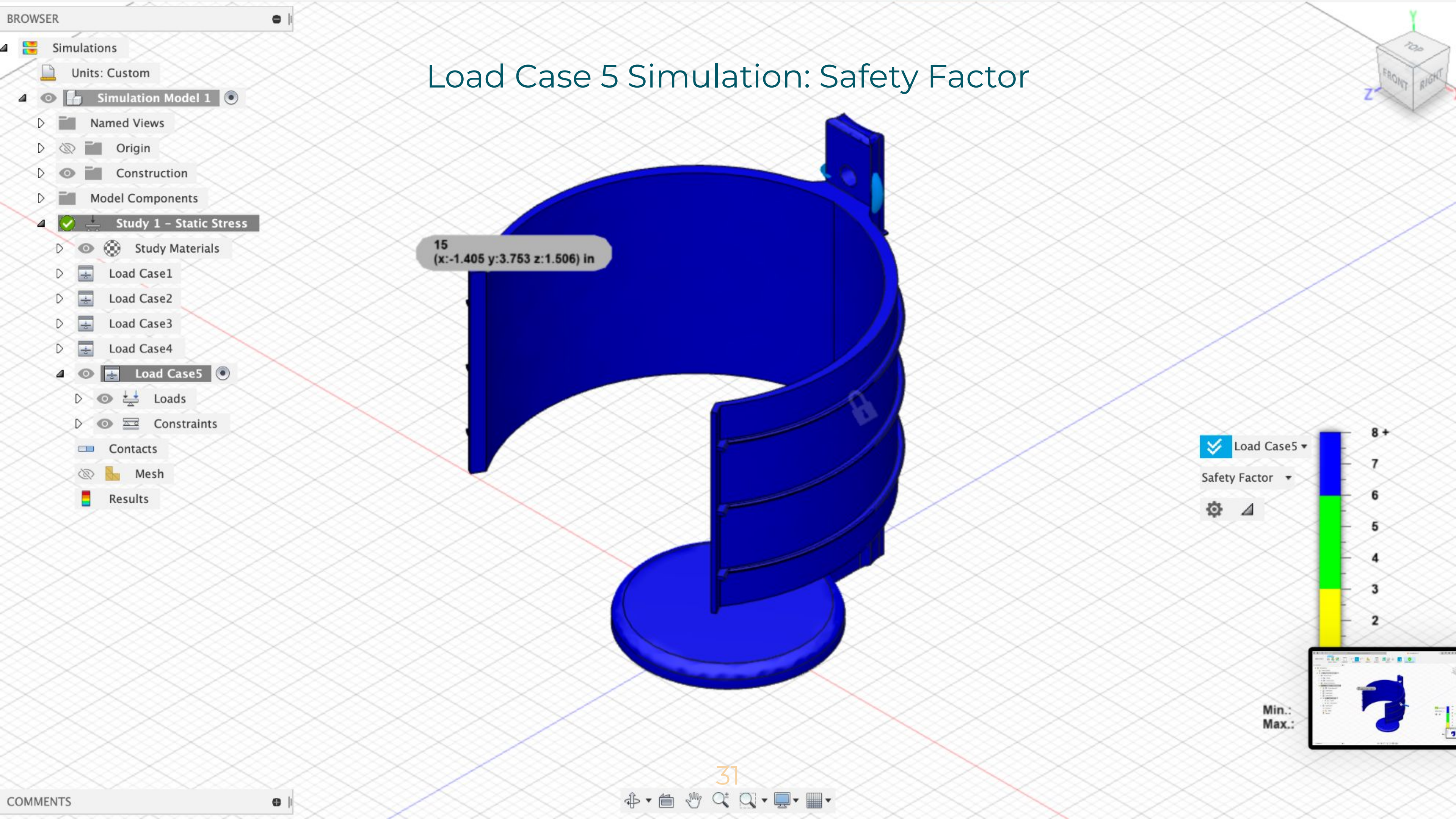
Load Case 4 Simulation: Safety Factor



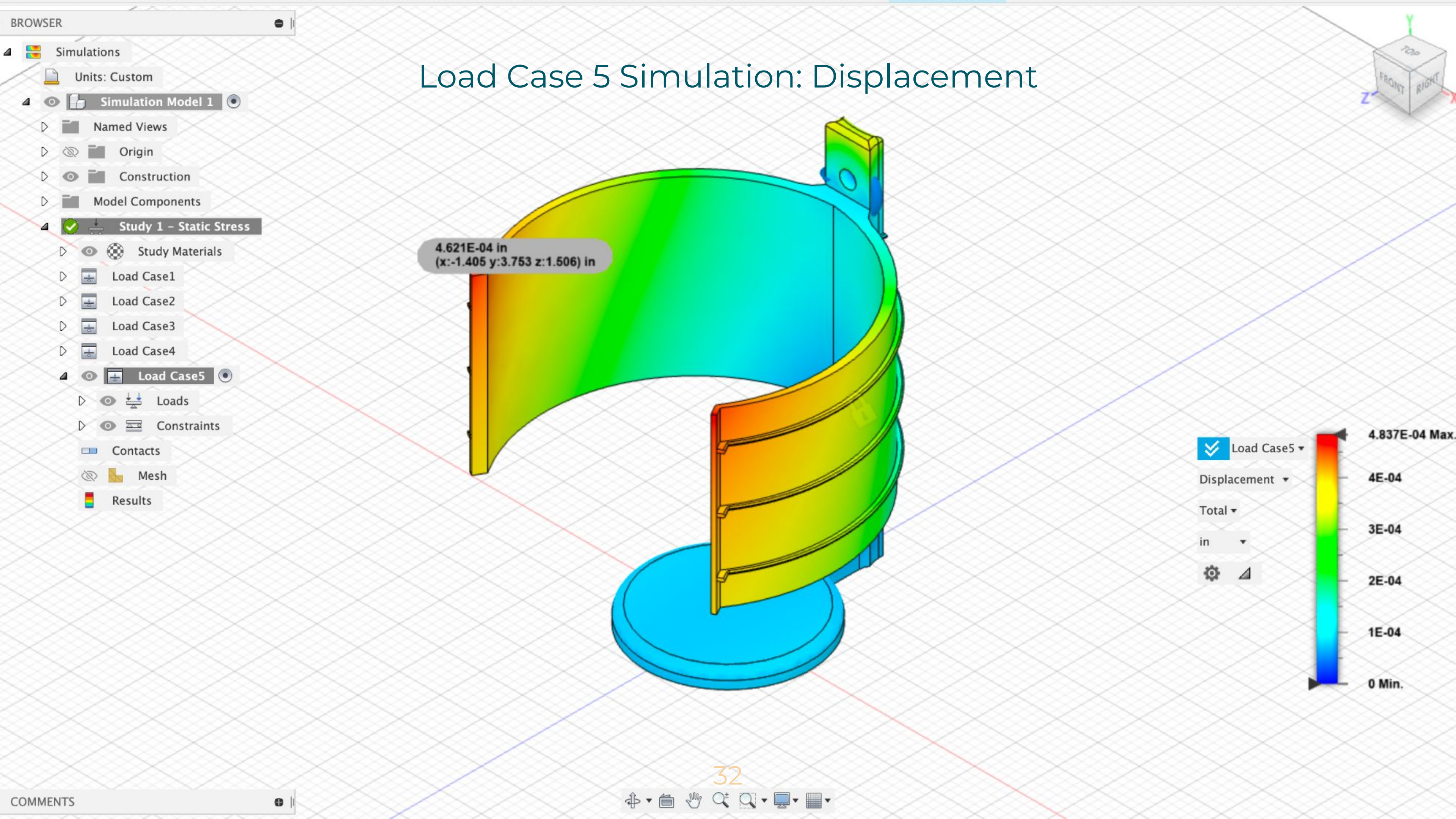
Load Case 4 Simulation: Displacement



Load Case 5 Simulation: Safety Factor

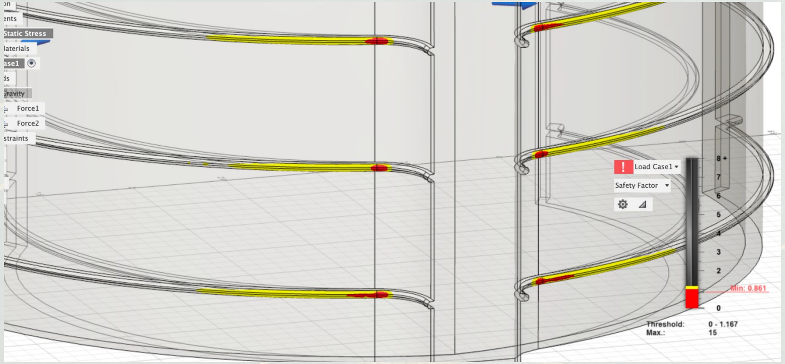


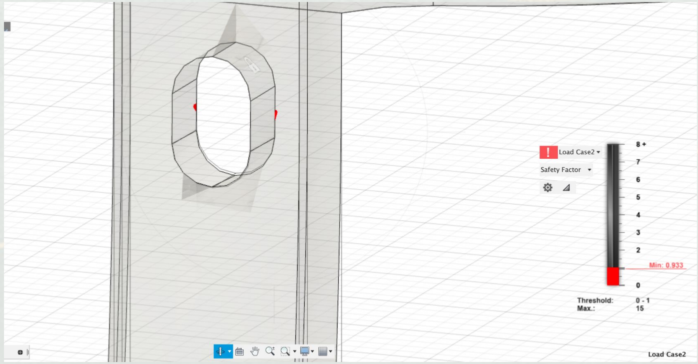
Load Case 5 Simulation: Displacement

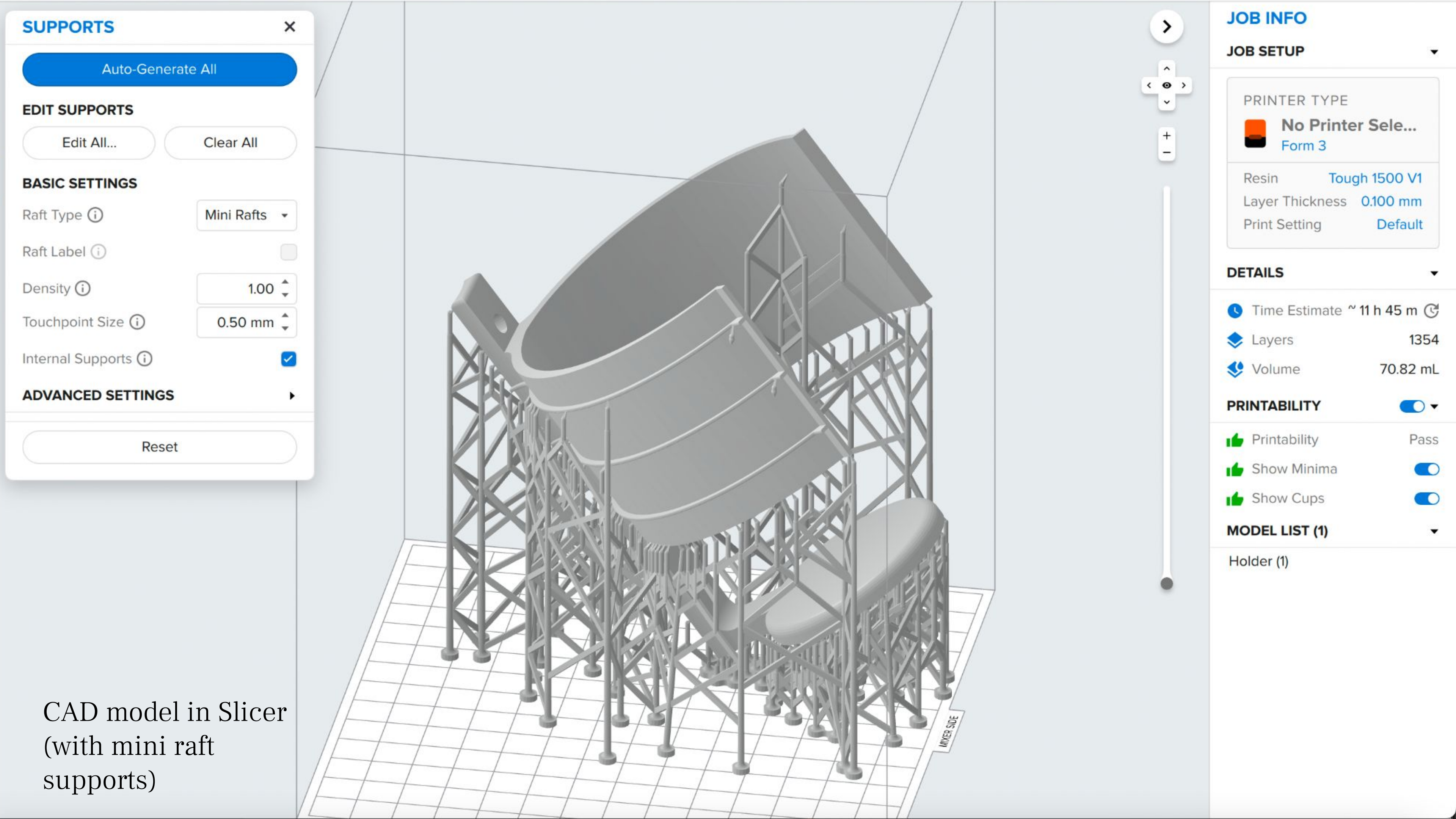


Simulation Analysis

Essentially, the simulation demonstrated that the design was strong enough to perform as necessary. The first two load cases, however, failed with a safety factor of 0.86 and 0.93, respectively. Following a discussion with numerous CAs, I decided that the failure points (at the external ribs and internal faces of the lower hole) were small enough to be neglected.



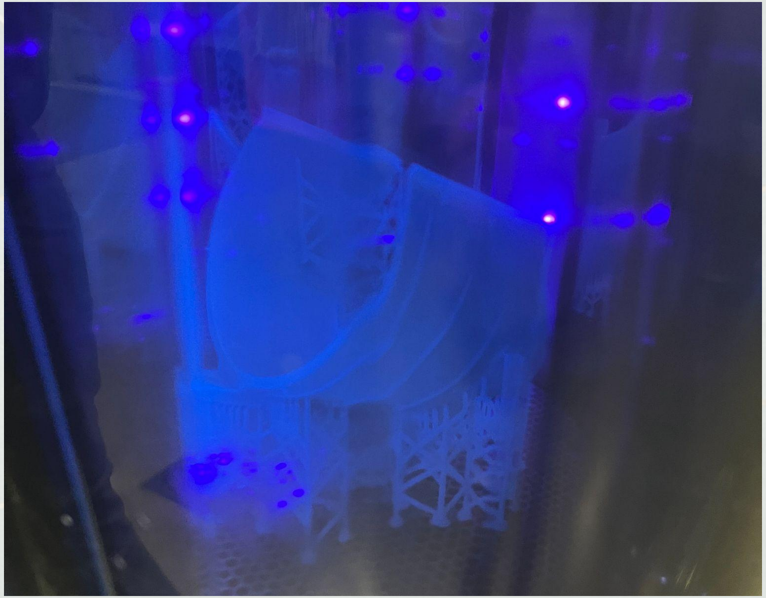




CAD model in Slicer (with mini raft supports)

Curing

I made sure to cure the model AFTER I washed it but BEFORE I took the supports off!



Final Product

Final Product

Final Product

Final Product

3.
Reflection

What Did I learn?

Analysis

My design was successful! The bottle holder mounts to my bicycle frame with no problem, and it seems more than capable of carrying my 32oz water bottle. The bottle slips in and out of the holder with ease and satisfaction–the holder is flexible enough to widen to the diameter of the bottle, but snaps back into place to the point where the bottle is nicely constrained, even with a significant amount of movement or inertia. When biking around, the bottle is nicely secured. If I had more time, I would consider how I could either make the design more adjustable to be capable of holding smaller bottles (but *who* drinks out of those?) or more mass efficient using algorithmic modeling–or who knows, maybe even both. However, as I am faithful to my 32oz water bottles, I am more than satisfied with my current design.

Reflection

I am more than pleased with the outcome of my final project, as I was able to imbue my academic learnings with a real world purpose. Although my final outcome deviated from my initial ideation, I was able to explore the iterative process and determine a solution that is much more suitable towards my intended outcome. I appreciate the help of the CAs and Dan who have–once again–provided me with valuable advice on how to elevate my design, approach the prompt from different perspectives, and continue pushing forward in the face of challenges. Admittedly, even though I had thought my initial idea was well-scoped, I found that it was, yet again, out of scope for the time-frame of the assignment. Moving forward, I will attempt to have a better understanding of project timelines to scope my project properly from the start. Furthermore, in the future I will take care to wash and cure my 3D printed part BEFORE I remove the supports, as that evidently makes a big difference.

Bill of Materials

Material	Cost
Test Prototype 1	$16.89
Test Prototypes 2-4	$9.36 ea (x3)
Final Prototype	$17.28
¼” Flat Nylon Washer, 95606A130	$0.20 ea (x2)
Total	$62.46

Design Time Estimate: 11 hours

Print Time Estimate: ~43.5