Project: Adjustable Desk Coaster

Design Brief

Problems: When drinks are left on various surfaces, then typically leave a ring of moisture at their base. This ring can ruin surface finishes, weaken materials, and/or leave unwanted marks on the table.

Constraints:

1) Must be able to fit various drink sizes snuggly
2) Must be able to stop drinks from spilling
3) Should not slide around freely on the desk
4) Stop the moisture of the cup from hitting the desk
5) Be relatively easy to clean
6) Fit all possible drink sizes in the base itself

Success Metrics:

- Efficiency (Interchangeable in less than 10 seconds) (uses minimal filament)
- Quality (Print looks clean and product is aesthetic)
- Reliability (works repeatedly)
- Performance (strong design)

Loads/Use Cases:

1) Normal Use: 10-40N
2) Max Effort: 40-80 N
3) Abuse: 100-250 N
4) Fatigue: 15-40 N cyclic

Manufacturing:

1) Manufacturing Method: The product will be manufactured using FDM #D printing. This method was selected due to low tooling costs, rapid iteration capability, and suitability for low volume or customized parts.
2) Material selection: Parts will be printed out of PLA because of low pricing, high supply, and strong enough toughness while maintaining good printability and toughness.
3) Manufacturing Constraints: This part should have wall thicknesses of 1mm and print orientation selected to align print loads with layer lines.
4) Post-Processing and Assembly: This will include support removal and light surface finishing. This will require no glue or adhesives and a small amount of screws to hold pieces together.

5) Manufacturing Success Metrics:
    - Print Success Rates >95%
    - Print time per unit < 8 hours
    - Assembly line <10 min
    - Functional fit without rework

Risks: Key risks include structural failure under abuse loading, dimensional variability due to FDM printing tolerances, and wear of the adjustable mechanism over repeated use. These risks are mitigated through conservative load assumptions, print orientation aligned with primary load paths, minimum wall thickness constraints, and simplified assembly features. Material selection and post-processing strategies further reduce environmental and user-related risks.

Test Plan: The project will follow a structured design process beginning with the definition of requirements, use cases, and load cases. Multiple adjustable coaster concepts will be generated and evaluated based on stability, manufacturability, and durability, after which a selected concept will be modeled with consideration for FDM manufacturing constraints. Prototypes will be 3D printed and tested under normal, maximum, abuse, and fatigue loading conditions, with iterative refinement applied based on test results. The final design will be validated through functional testing, durability evaluation, and manufacturing repeatability prior to documentation and final delivery.

Iteration Notes

Version: 1

Change Made: The cup holder attachments were made to snuggly fit assorted cups, bottom of cup holders were made smooth, and the lower storage was slotted.

Why: These changes were made to prevent spills, promote easy cleaning, and so that the other attachments were kept in one place.

Results: The overall finish of the product was much cleaner. Furthermore, the cup bases were noticeably easier to wipe dry and clean. The cups were far more stable and the desk was kept dry.

Sim Results

This static FEA validates that the desk coaster maintains a factor of safety greater than two under a force for 15N normal to the base.

Material properties:

1) PLA

2) Elastic modulus: 435,000 psi

3) Poisson's ratio: 0.35

4) Yield / ultimate strength: 65 MPa

5) Density (if relevant): 1.25 g/mL

Loads and Boundary Conditions:

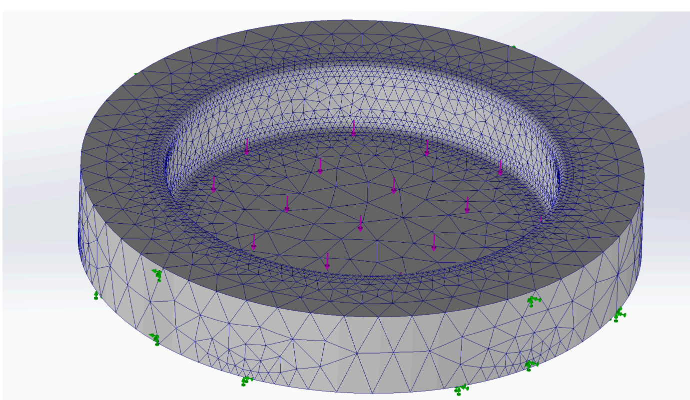
- Load magnitudes and directions: 40 N force downward normal to the base representing the relative maximum force expected to be exerted on the base by an average cup.

- Load locations: This force is to be exerted on the circular base face where the cup is placed and should be normal to the surface face.

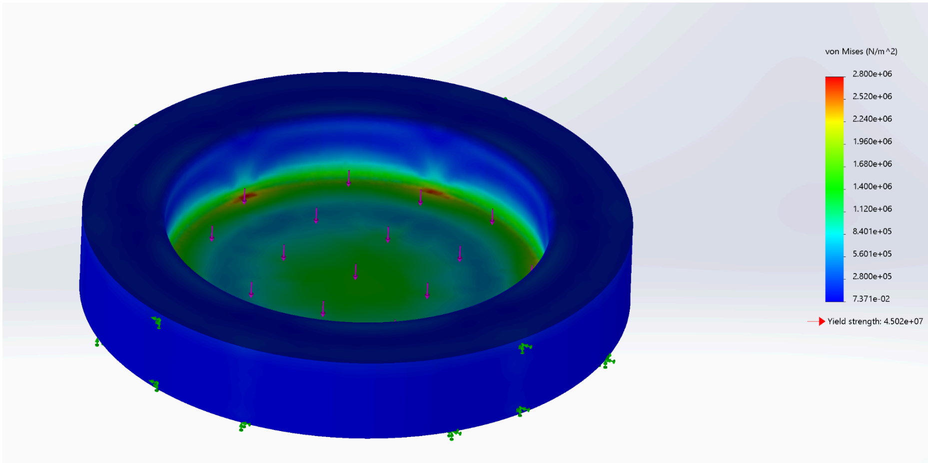
- Constraints / fixtures: The base of the interchangeable coaster base is fixed at the bottom by a normal force applied by the desktop surface, and the outer cylinder is fixed as well as it is supported by the cylinder it sits in.

Results:

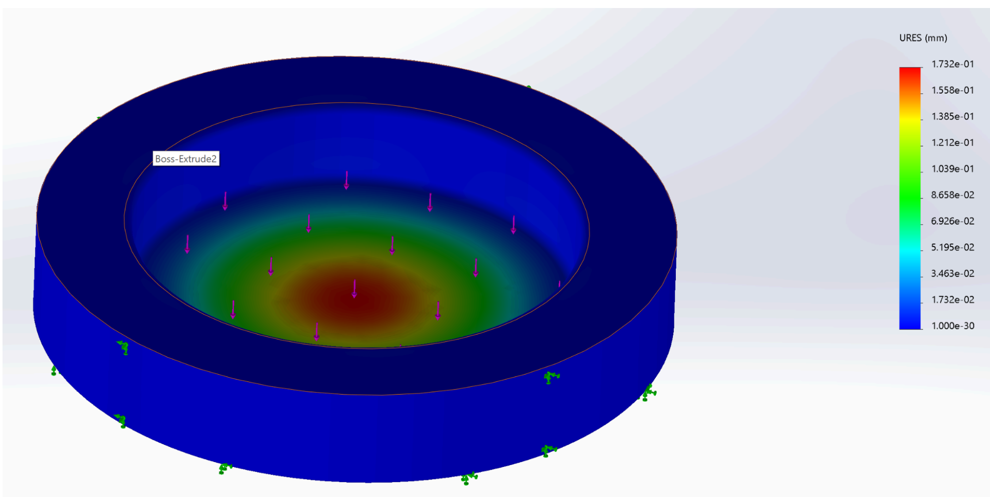
- **Mesh Plot:**



- **Max von Mises stress:** The maximum von Mises Stress of 2.8 MPa occurs at the fillet root, below the 45 MPa yield strength. (FoS = 16.1)



- **Max displacement:** The maximum displacement is 0.17 mm at center of the base under 40N; this is acceptable compared to the allowable deflection of .32 mm.



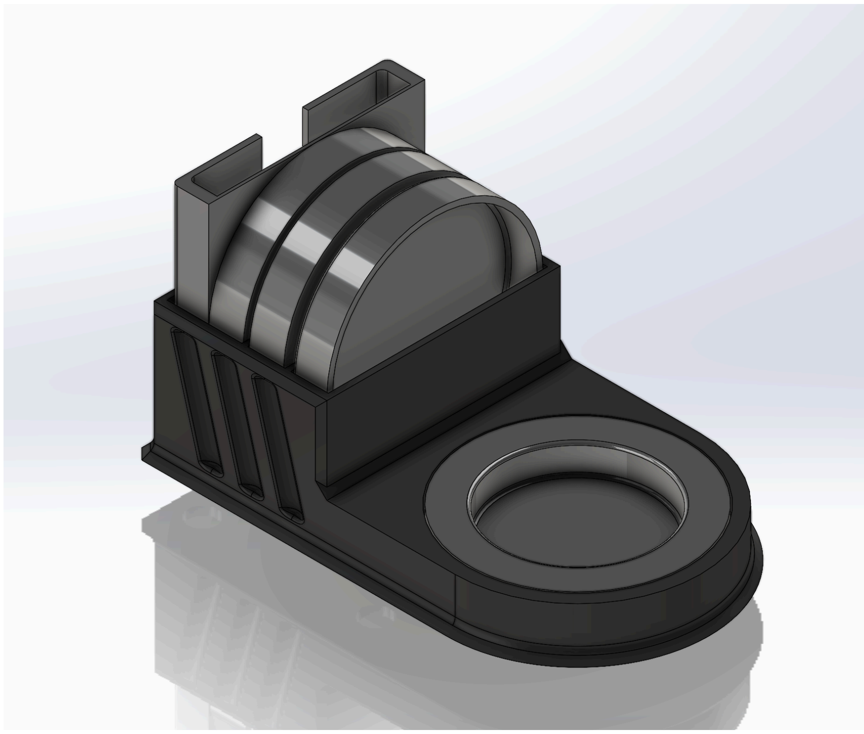
- **Factor of Safety:** The factor of safety against yielding is 16.1, calculated using a maximum von Mises stress of 2.8 MPa and a PLA yield strength of 45.0 MPa, indicating the design is well within elastic limits under the 40 N load case.

Limitations & Assumptions:

- Ignored real-world effects (fatigue, temperature, wear, impact)
- Idealized constraints
- Manufacturing tolerances not included
- Material variability

Sim Conclusion: This design fits well within its limits strength wise. It is very acceptable and should last a long time in almost any circumstance.

Final Model



Overall Conclusion:

The Adjustable Desk Coaster was developed to address a common but often overlooked problem in everyday workspaces: moisture damage and instability caused by beverage containers placed directly on desk surfaces. Condensation that forms at the base of cups can leave rings, weaken surface finishes, and permanently damage desks, while cups of varying sizes can be prone to tipping or spilling. The goal of this project was to design a single, adaptable solution capable of securely supporting a wide range of drink sizes while isolating moisture from the desk surface and maintaining a clean, aesthetic appearance.

The design was guided by several functional constraints, including the need to fit multiple cup sizes snugly, prevent spills during normal and excessive use, resist sliding on the desk, and block moisture from reaching the surface below. Additional considerations included ease of cleaning, durability under repeated use, and the ability to store interchangeable components within the base itself. Success was defined by a product that could be adjusted in under ten seconds, used minimal material, printed cleanly, and performed reliably over repeated loading cycles without degradation.

Manufacturing considerations played a central role in the design process. The coaster was designed specifically for fabrication using fused deposition modeling (FDM) 3D printing, which was selected due to its low tooling cost, rapid iteration capability, and suitability for low-volume or customized parts. Polylactic acid (PLA) was chosen as the material because of its low cost, high availability, good stiffness, and reliable printability. Design constraints such as minimum wall thicknesses of 1 mm and print orientations aligned with primary load paths were incorporated to improve strength and reduce the likelihood of interlayer failure. Post-processing requirements were intentionally kept minimal, consisting only of support removal and light surface finishing, while assembly was simplified to require no adhesives and only a small number of fasteners.

The coaster was evaluated under a range of realistic use cases, including normal use loads between 10 and 40 newtons, maximum effort loads up to 80 newtons, abuse loading as high as 250 newtons, and cyclic fatigue loads between 15 and 40 newtons. A representative static finite element analysis was conducted using a conservative 40-newton downward force applied normal to the circular base where a cup would rest. This load was selected to represent the upper bound of expected forces during typical use while maintaining a margin for unexpected user behavior.

The simulation was performed using generic PLA material properties, including an elastic modulus of 435,000 psi, a Poisson’s ratio of 0.35, and a conservative yield strength of 45 megapascals. Boundary conditions assumed the base of the coaster was constrained by the desk surface, while the outer cylindrical geometry was supported by the surrounding base structure. Although idealized, these conditions reasonably represent real-world use and provide a meaningful assessment of structural performance.

Results from the finite element analysis demonstrate that the design operates well within both strength and stiffness limits. The maximum von Mises stress of 2.8 megapascals occurs at the fillet root and remains far below the conservative yield strength of PLA. This corresponds to a factor of safety of 16.1 against yielding, indicating that the design is significantly over-designed from a strength perspective under the applied 40-newton load. Maximum displacement occurs at the center of the base and measures 0.17 millimeters, which is below the allowable deflection of 0.32 millimeters derived from 25 percent of the available 0.05-inch clearance. This confirms that deflection does not compromise fit, stability, or function.

Throughout the iteration process, refinements were made to improve performance and usability. Adjustable cup holder attachments were modified to provide a snug fit for assorted cup sizes, reducing the risk of spills. The bottoms of the cup holders were smoothed to simplify cleaning and prevent moisture retention, while the lower storage region was slotted to securely retain unused attachments. These changes resulted in a cleaner overall appearance, improved stability, and easier maintenance without increasing manufacturing complexity.

While the analysis provides strong confidence in the design, several limitations remain. Real-world effects such as long-term fatigue, temperature exposure, wear, impact loading, manufacturing tolerances, and material variability were not explicitly modeled. However, conservative material assumptions, aligned print orientation, and simplified load paths help mitigate these risks and support reliable real-world performance.

In conclusion, the Adjustable Desk Coaster successfully meets all functional, manufacturing, and performance objectives defined at the outset of the project. Structural analysis confirms that the design remains well within allowable stress and deflection limits, with stiffness rather than strength governing performance. The final design offers a durable, adaptable, and aesthetically clean solution for protecting desk surfaces from moisture damage while securely accommodating a wide range of drink sizes. As a result, the product is expected to perform reliably over extended use and serves as a strong example of practical, analysis-driven engineering design.