Critical Design Review: Spur Gear Transmission

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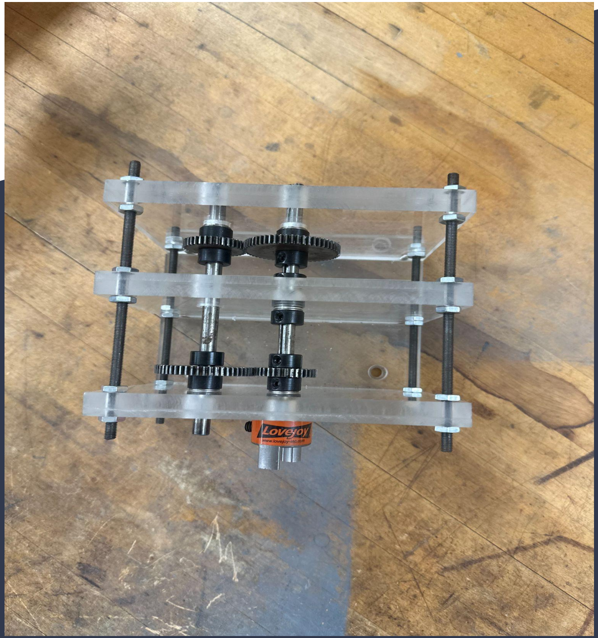
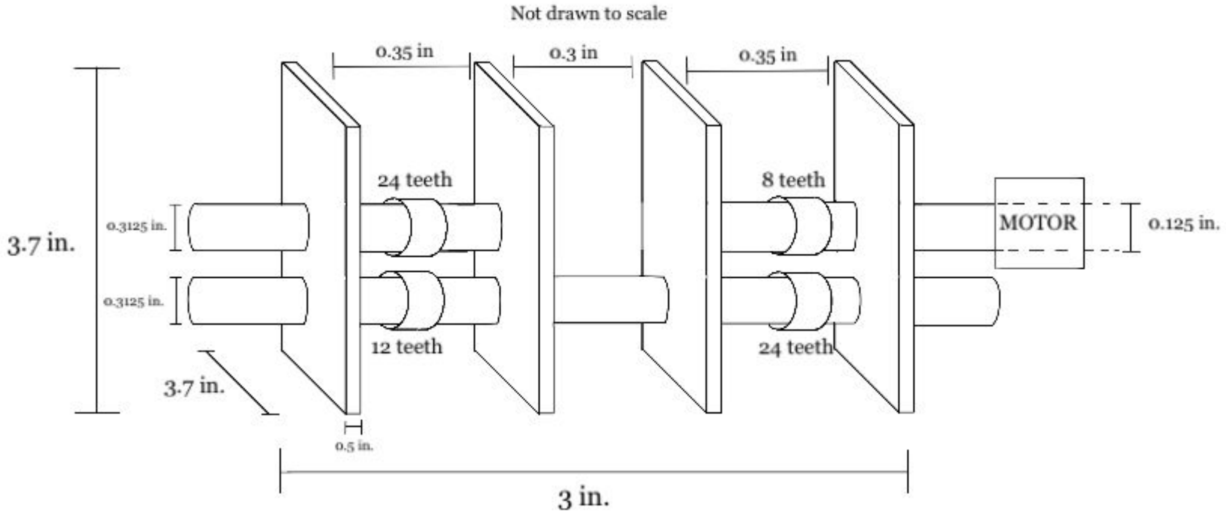
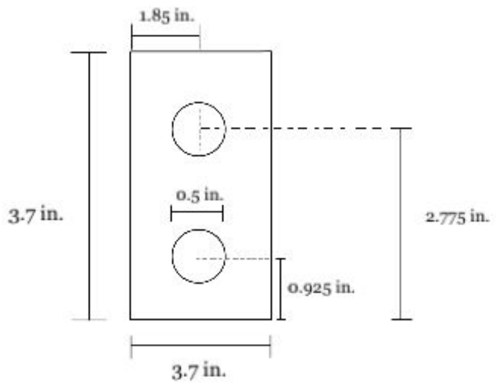


Design Overview: Transmission Design Concept

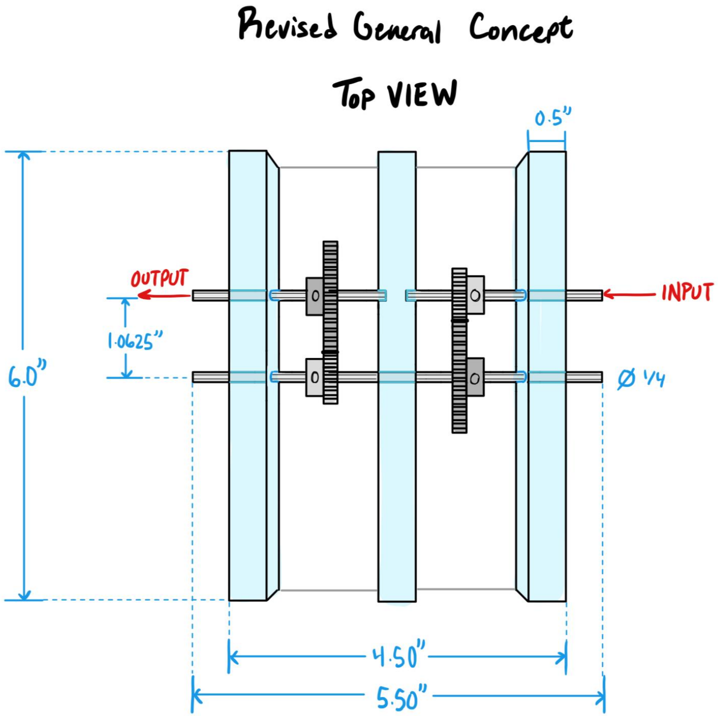
- Reverted gear train
- Four spur gears with total gear ratio of 6 : 1
  - Each set has gear ratio of 2.45 : 1
- Using 6” x 3.625” x 0.5” acrylic supports with holes to accommodate for motor and two shafts.
- Dimension of whole transmission is 5.5 x 4 x 6 in^3
- Dimension including bottom base plate 6 x 4 x 6 in^3
- Refer to drawings later in presentation for more detail

Design Overview: Initial Concept

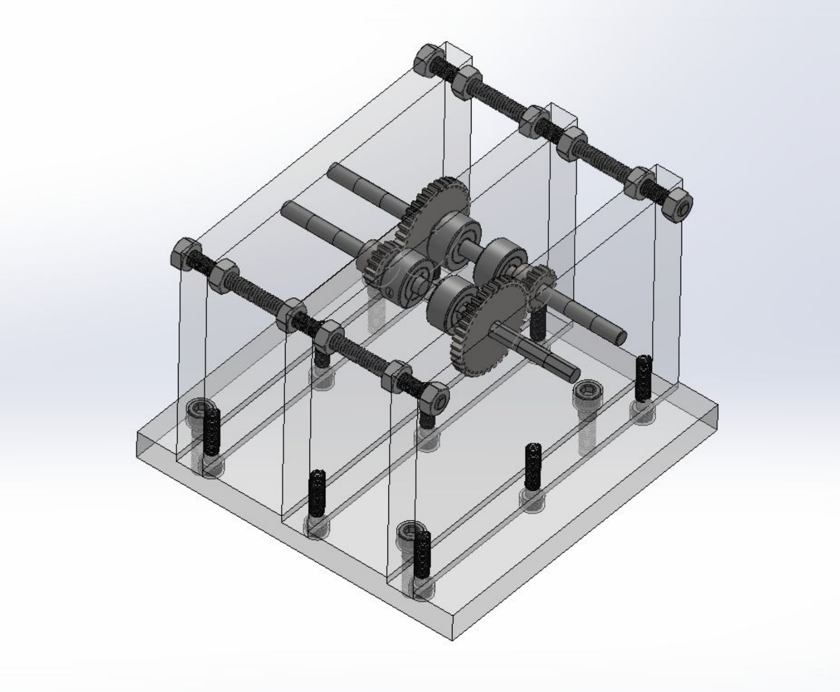


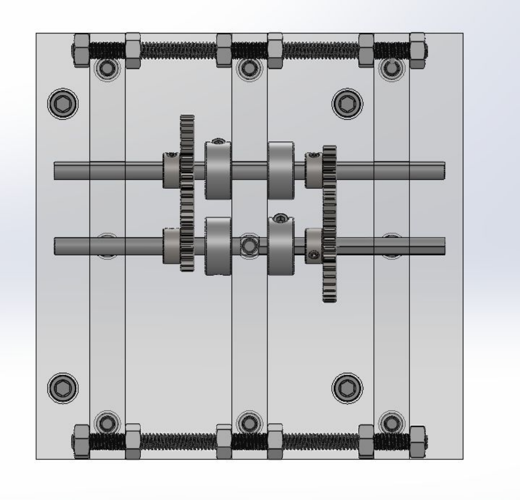


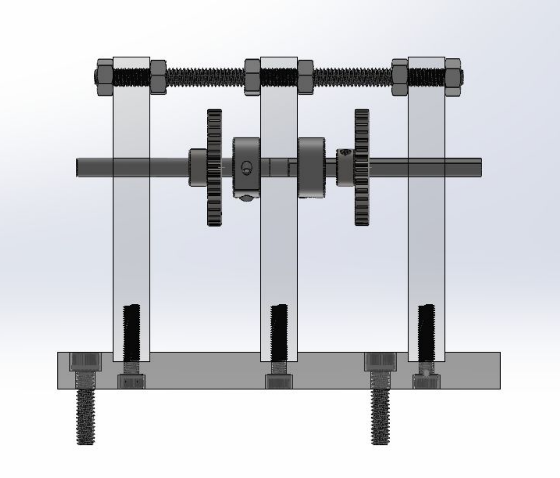
Design Overview: Rough Revised Concept



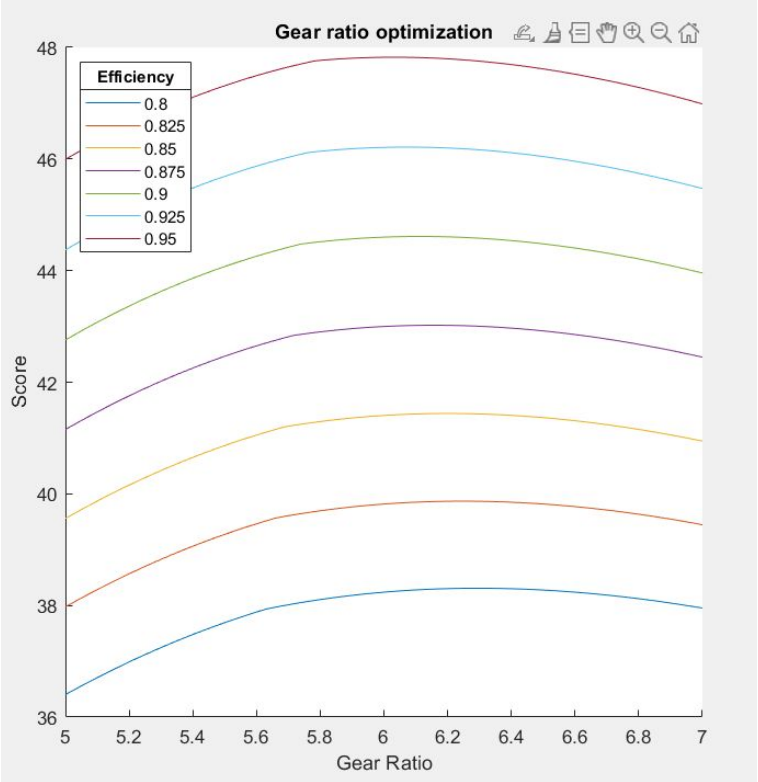
Design Overview: CAD Model

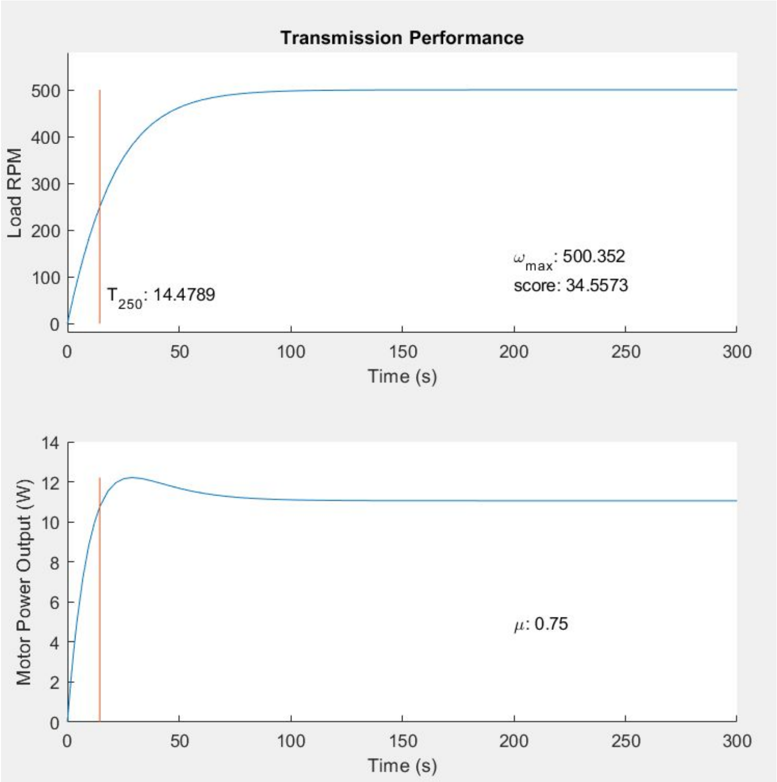






Design Rationale (Overall Gear Ratio)





Design Rationale (Gear Ratio + Component Selection)

Optimal Gear Ratio

The MATLAB script provided on Canvas was used to find the optimal gear ratio between 5 and 7. Lines 43-44 and lines 74-75 were kept the same as they reflected the constraints of this project. We determined the ideal ratio of 6.0 ± 0.2 for the various efficiencies.

Individual Gear Ratios

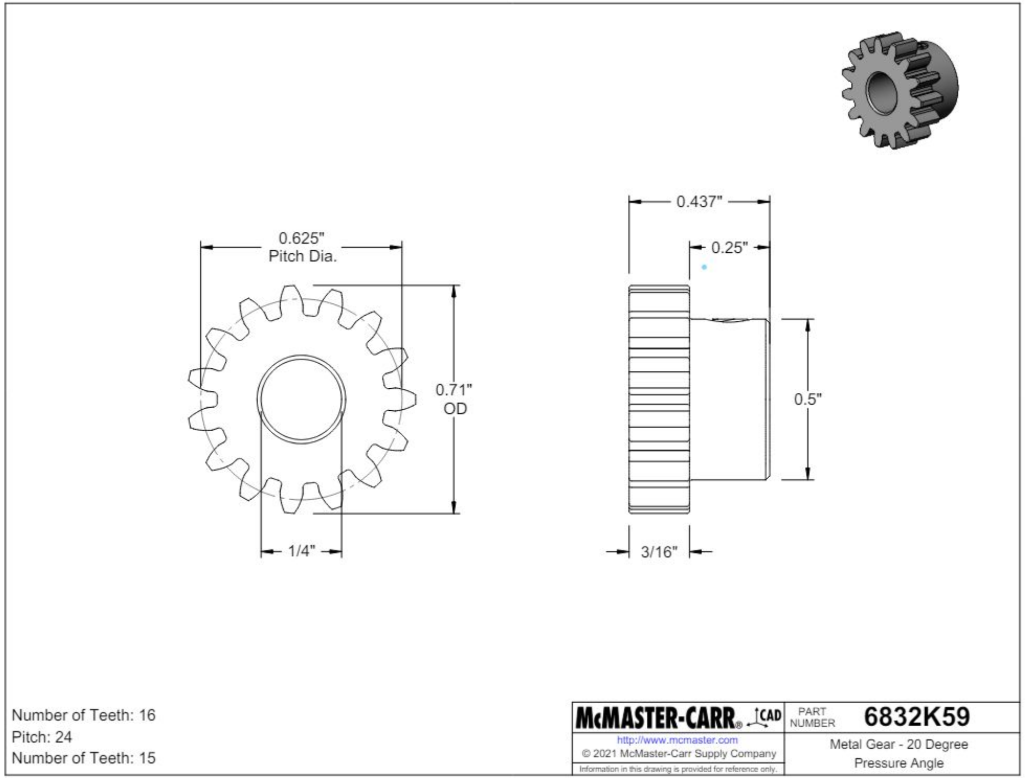
Our goal is to find a pair of gears that yields an overall gear ratio of 6 when two sets of the pair are used, that is,

$$\frac{N_2}{N_1} \cdot \frac{N_4}{N_3} = 6$$

for $N_1 = N_3$ and $N_2 = N_4$. Thus, $\dfrac{N_{2,4}}{N_{1,3}} = \sqrt{6} \approx 2.45$.

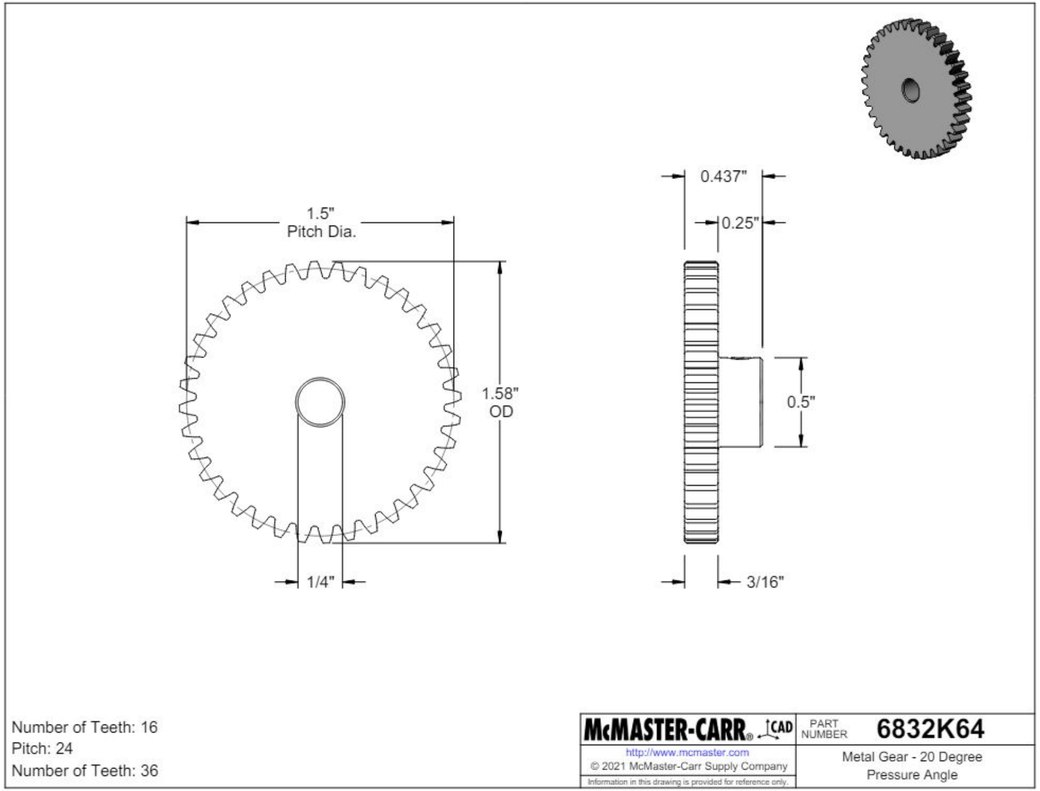
Looking at the list of possible gears under a 1/4" shaft diameter and sharing the same 20° pressure angle, we found the optimal pairing of gears to be between the 15- and 36- tooth gears, both having a 24 gear pitch. This pairing yields an individual gear ratio of 2.4 and an overall gear ratio of 5.76.

Design Overview: 15 Gear Drawing Files



Carbon Steel
15 tooth gear

Design Overview: 36 Gear Drawing Files



Carbon Steel
36 tooth gear

Design Rationale (Shaft Selection + Dimensioning)

The shaft must be constrained by:

- The 36-teeth gear
  - 0.437”
- The 15-teeth gear
  - 0.437”
- Three acrylic plates
  - 0.5” $\times$ 3 = 1.5”
- Shaft collar
  - 0.375” $\times$ 2 = 0.75”

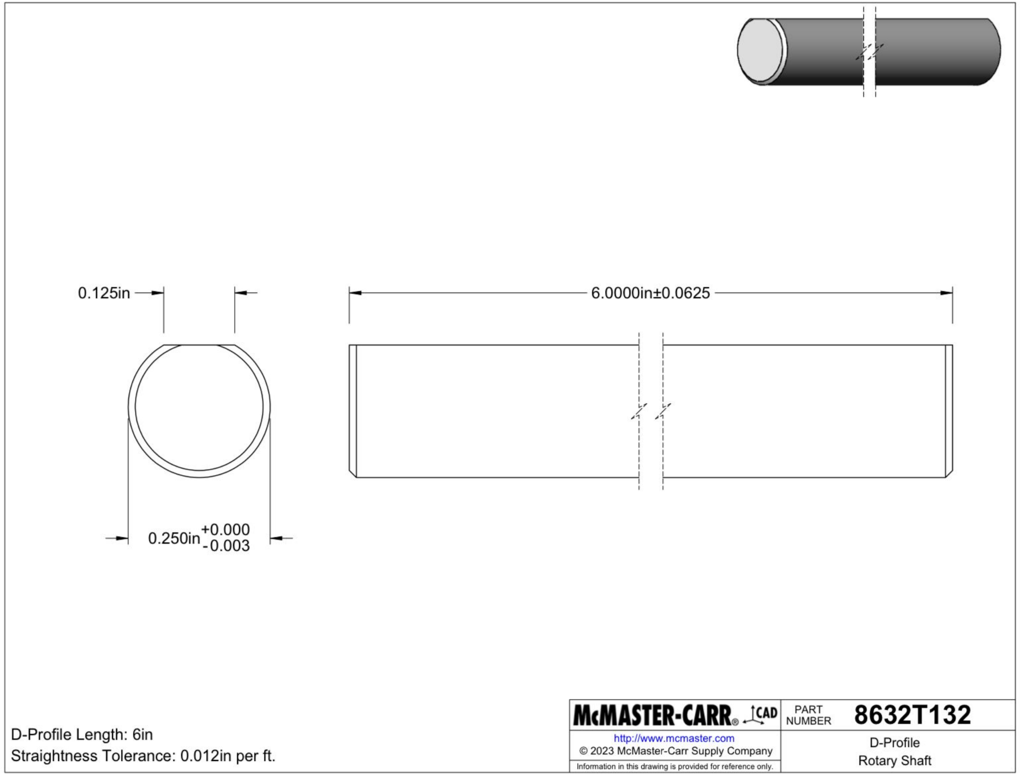
. . . resulting in an individual minimum shaft length of 2.75”.

We also consider optimal clearances. For there to be a clearance of 0.5” between each end of the shaft and the corresponding acrylic plate, we choose the long shaft length to be 5.50” total. For the shorter shafts, we allow a 0.125” depth of each shaft interface with the center acrylic plate, meaning the lengths of the smaller shafts will be 2.625” each.

The diameter of the shaft will be ⌀ 1/4” to accommodate gear selection. We choose a D-profile shaft due to ability of gear attachment with set-screws.

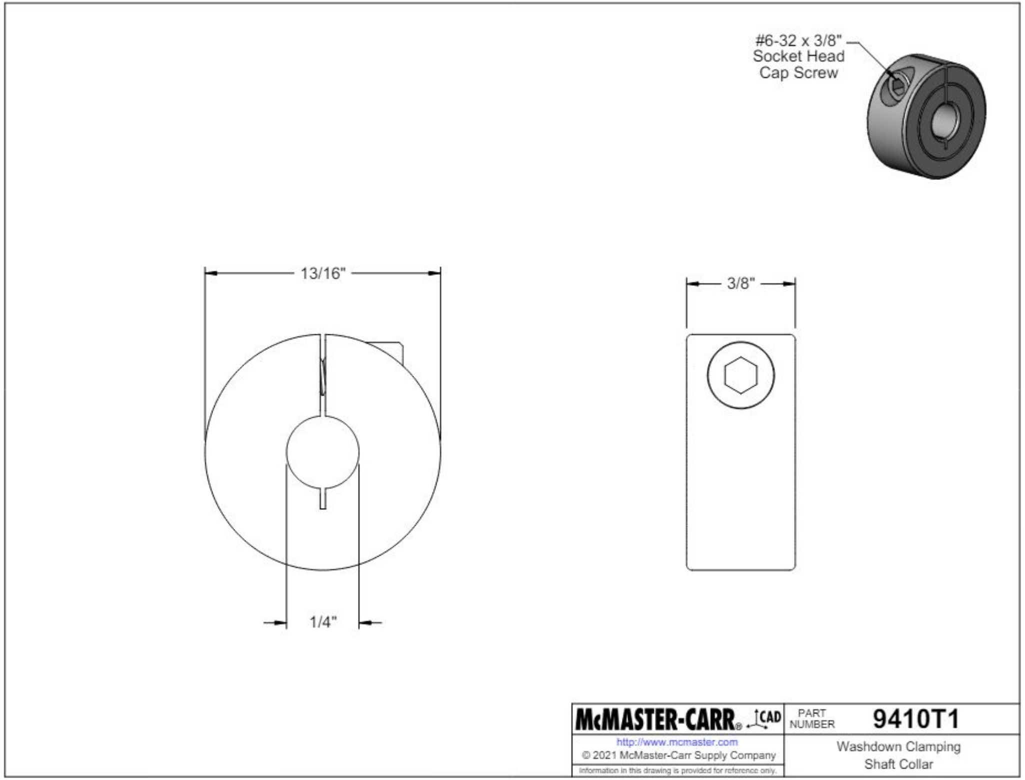
Shaft will be axially constrained with shaft collars at acrylic interfaces

Design Overview: Shaft Drawing File



Aluminum
D-profile shaft

Design Overview: Shaft Collar Drawing Files



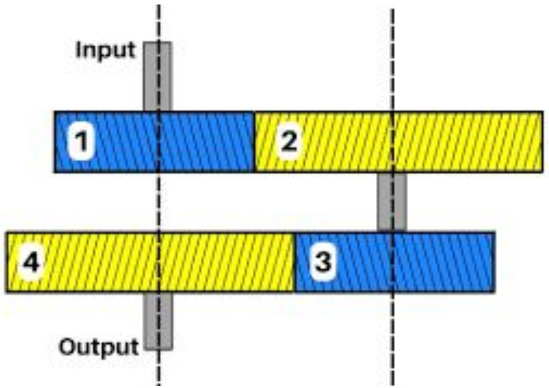
Washdown Clamping Shaft Collar

Design Rationale (Acrylic Plates)

- Three 6" × 4" × 0.5" acrylic plates
- **Sizing**
  - Width: 6" to make machining acrylic easier
  - Machine by:
    - Cutting only one dimension via the band saw
    - Machine down two (out of four) sides on mill
    - Drill holes where screws go with appropriate drill and WD-40
    - Mill tap drill these holes
- **Bore Holes**
  - Position:
    - Driving bore hole near the center of the plates' width
    - Allows for motor attached 3" up
    - Bore placement based on thickness of bottom plate minus depth of attachment slots
  - Both ⌀ 1/4" holes have 1.0625" center to center distance (radial gear width)

Design Rationale (Overall Skeleton)

- Changed the orientation to be horizontal rather than vertical due to height constraints and visual clarity.



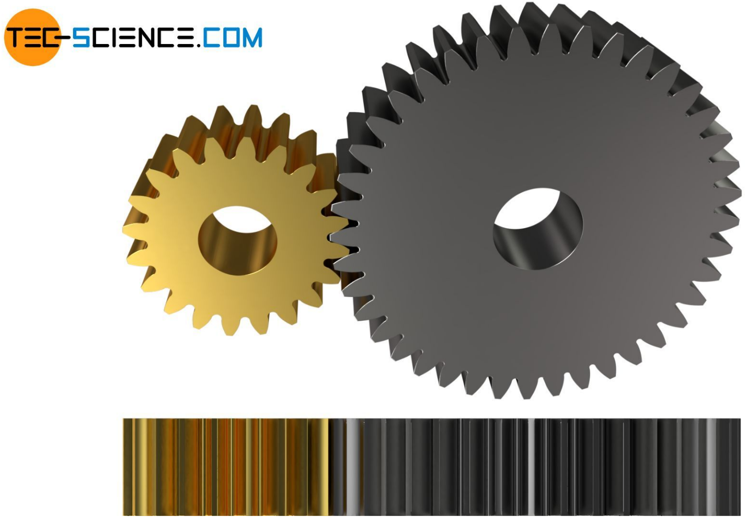
Constraints

- The dimensions of the skeleton were based on the outer diameters of the gears meshed together in the reverted gear train.
- Length: 5in (base acrylic 6 inches long to accommodate mounting)
  - To accommodate three 0.5” thick acrylic plates and 0.6835” space either side for 0.437 in thick gears (including built in bearing) 0.25 in thick gears stand alone
- Height: 4in
  - To accommodate largest gear on the top shaft located 3 inches above the ground plate
    - (15 and 36 teeth gears stacked together at 2.125 inches)
    - 15 tooth gear radius is 0.355 in
    - 36 tooth gear radius is 0.79 in

Design Rationale (material)

- Acrylic is readily available, transparent, cheap, sturdy for purposes of project

- Carbon steel is the most ideal material for the gears (1)
    - Allows for ease of machining (if needed)
    - Relatively inexpensive
    - Widely available
    - Good wear resistance (reliable for multiple tests)
    - Mcmaster gears come with set screws
    - Bearings/reverted rings provided will hold gears in place as well



Summary of Research and Analysis

Material Research

- Found materials for gears available on McMaster and researched benefits applicable to project.
- Considered the use of materials already provided to us (machinability, cost, etc.)
- Discussion of past experience working with these materials

Design Skeleton + Changes

- For size requirements, opted for a reverted gear train design
- Used duplicate gear ratio to ensure coaxial input and output shafts
- Rotated our design 90° so that shafts are parallel along horizontal, rather than vertical, axis due to dimensional concerns.
- Changed shafts to a D-shafts so that gears can be constrained via set-screws.
- Using four nylon bearings to aid shaft rotation

Gear Ratio

- Evaluated required torque and implemented MATLAB script to determine ballpark gear ratio
- Decided on target gear ratio of 6
- Found optimal available gear teeth numbers to be 15 and 36
- Overall gear ratio of 5.76

Design Dimensions

- Made sure that the whole transmission would not exceed the inner dimensions of the plexiglass box
- Made sure that the gears all fit together by examining diametrical pitch and creating CAD model
- Provided 1-inch buffer room on top and bottom for gear train
- Length of acrylic 4.125” for ease of machining
- Considered thickness of acrylic, gears, and retaining rings within transmission as well as a buffer space of $0.125 - 0.2$ inches for each gear

Bill of Materials (BOM)

	MEMBERS	TEAM #	PART #	DESCRIPTION	QTY	INDIVIDUAL COST	SUBTOTAL	TOTAL	
MCMASTER-CARR ORDER	Kristi, Sevier Sara, Razavi Jaylen, Shawcross Bella, Mueller	5	6832K59	Carbon Steel 15-	2	$19.52	$39.04		
		5	6832K64	Carbon Steel 36-	2	$30.62	$61.24		
		5	8632T139	1/4 in diameter	1	$10.86	$10.86		
		5	9410T1	1/4 in diameter beari	4	$11.13	$44.52		
		5	3313N154	1/4 -20 5" steel	2	$8.93	$17.86		
		5	90499A029	1/4" - 20 high	1	$7.32	$7.32	$180.84	
							$0.00		
							$0.00		
							$0.00		
							$0.00		
							$0.00		

Design Analysis + Efficiency

Theoretical: 5500RPM → 955RPM

PROS

- Easy to manufacture
- Fewer materials - fewer variables
- Fits well within box dimensional parameters
- Mathematically-driven gear ratio design
- Well-spaced (less friction)

CONS

- Moderately expensive - provides little budgetary tolerance
- Does not reach our theoretical optimal gear ratio (5.76 ≠ 6)
- Further testing required to determine discrepancies in practical application

Schedule

Date	To-Do List
May 14, 2024	• Critical Design Review Presentation • Final Bill of Materials • Final Design Drawings
May 16, 2024	• Fabricate acrylic walls & shaft
May 17, 2024	• Assemble Transmission Box • Test
May 20, 2024	• Major Fabrication Milestone
May 23, 2024	Transmission Contest!

Works Cited

1. Dengel, B. (2021, January 15). Finding the ideal materials for gears | Gear Solutions Magazine Your Resource to the Gear Industry. https://gearsolutions.com/features/finding-the-ideal-materials-for-gears/#:~:text=The%20copper %20base%20of%20brass