MIE 243 - Dissection 5 - Gearbox Design (Option 2 + Bonus)

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1. Engineering Specifications

Before proposing a final design, we thoroughly analyzed the problem statement and presented the design specifications using the Black Box method:

INPUT	
Motion type	Rotational (continuous)
Motion properties	Low speed, low torque (hand movement)
Other constraints: Input must be parallel and collinear with output (As part of the BONUS Question)	

OUTPUT	
Motion type	Rotational (continuous) → same as input
Motion properties	$\omega(out) = \omega(in) * 1/12$ $\tau(out) = \tau(in) *12$
Other constraints: Output must be parallel and collinear with input (BONUS)	

Core requirements (directly from problem statement):

- Design must implement a speed reduction ratio of approximately 12:1
- Design must have parallel and collinear input and output
- Design Must be able to be 3D printed in less than 6 hours
- individual parts must fit within a build area of 155 x 170mm

Expanded requirements (from our interpretation/clarification):

- Design must minimize cost - Design must maximize robustness.

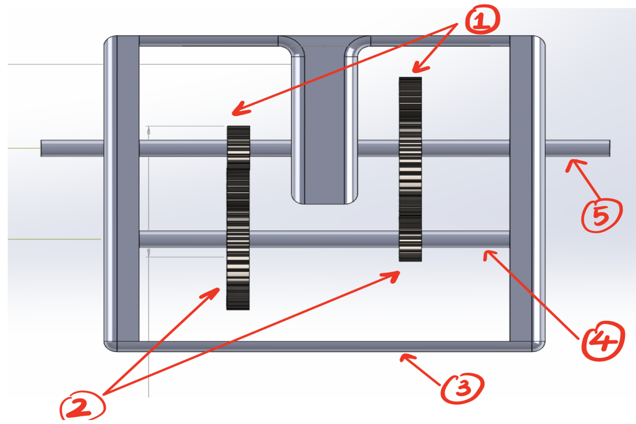
2. Idea Generation

We broke down the problem into three sub-problems:

a) Obtaining a speed ratio of at least 12:1 reduction
b) Making the input and output shafts parallel
c) Making the input and output shafts co-linear

The minimum viable design using a single gear pair and fewest possible parts to achieve a 12:1 reduction ratio would require a small gear and a very large one (N(output) = 12*N(input)). This design choice would incur a high cost since the output gear would likely be not standard (large size/ tooth count). Moreover, this design would not be flexible to make the input and output shafts co-linear.

Therefore, we decided to add a second active gear pair. This removes the need for expensive custom gears since both pairs have an approximate ratio of 6:1. It also allows for both collinear and parallel design variations.



3. Parts List and Justification

Gears [1,2]: We chose two pairs of 32 diametral pitch Spur Gears (one pair with 14 teeth and another pair with 49 teeth). 14 teeth gear **[1]** and 49 teeth gear **[2]** on the two small shafts acted as the input and output respectively. Spur gears were preferred over other gears like Herringbone, worm gears etc. to avoid less complexity in printing and dimensioning. The presence of 14 teeth and 49 teeth gears provided us a teeth ratio of 3.5 (49/14), which with the presence of two pairs meant a 3.5*3.5 = 12.25 speed reduction ratio, slightly more than the 12:1 ratio asked for.The gears were set at 0.20" Face Width to improve the contact ratio between them and reduce the backlash and noise from the vibrations present, while at the same time, minimizing the printing time. For manufacturing, we would prefer using Herringbone gears instead of spur gears to improve performance as it is a helical gear as well as reduce the need of having bearings due to its ability to sustain against high torque.

Shafts [4,5]: 3 shafts were used in our gearbox – 2 identical small shafts **[5]** were used as the input and output shafts supporting the input and output while 1 longer shaft **[4]** was used to support the other gear pair. The shaft diameters were set at 3/16 (4.76mm), which fit within the constraints as required to be less than 3/8 in. The shafts extended outwards by 20 mm from the design. The shafts were flattened from one side to improve print quality as mentioned in the slicing manual.

Housing [3]: We designed the housing as a rectangular box since it minimizes the amount of sharp edges which allows for a faster 3D printing time. Moreover, since the input and output shafts had to be collinear and parallel, we decided to separate them with a thick wall, to provide structural toughness and reduce the moment arm caused by the gears. This led to a U-shaped design of the gearbox. Further, we decided not to include a roof, floor and we cut out holes in the walls **[3]** since they do not add any structural integrity to the design (they are not in contact with any of the other parts). This helps minimize the amount of material required, which therefore minimizes the 3D printing time. Finally, we also applied fillets on every edge and corner of the design to further reduce the printing time.

Supports/Bearings: In an ideal situation, roller bearings would be used between the shafts and the walls of the housing to allow for smooth rotation of the shafts and to reduce backlash/noise. However, we are restricted by the 3D printing conditions which force us to minimize the amount of parts used. Since the roller bearings are not necessary to the functionality of the design, we decided not to include them even though they provided great benefits for the overall quality of the gearbox.