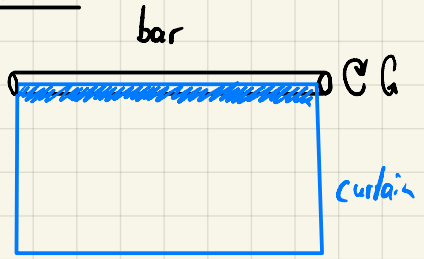
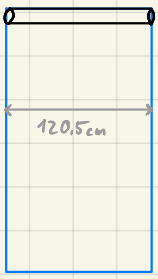
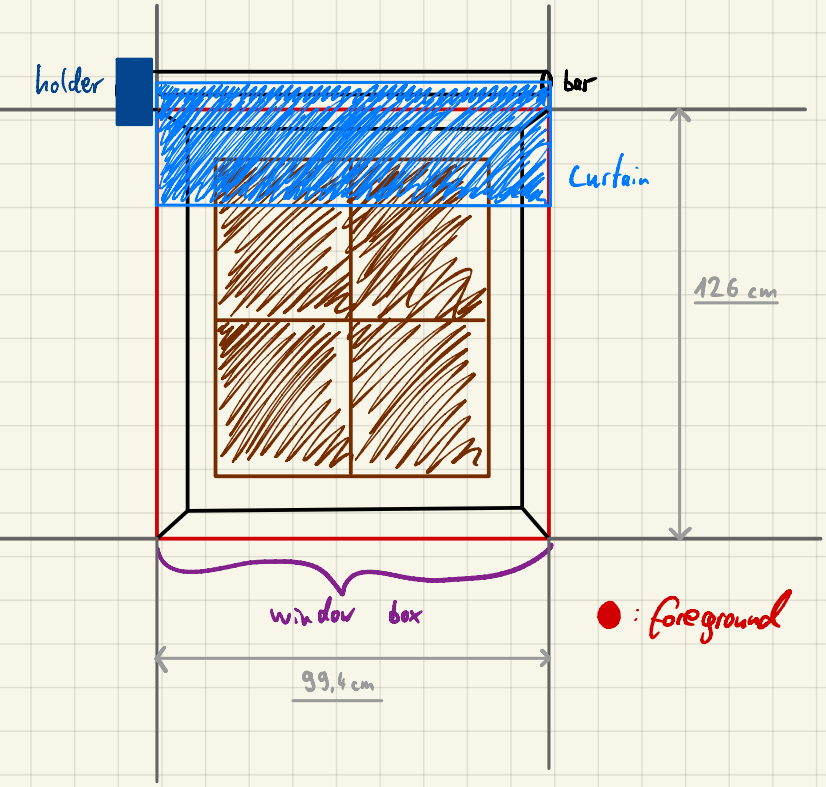
very abstract:



curtain



wind up 126cm: 8 rotations bar



● : foreground

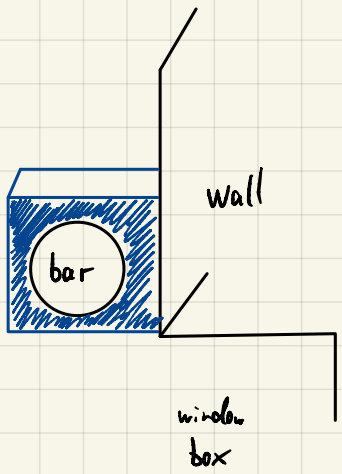
option 1: ~~bar inside window box~~

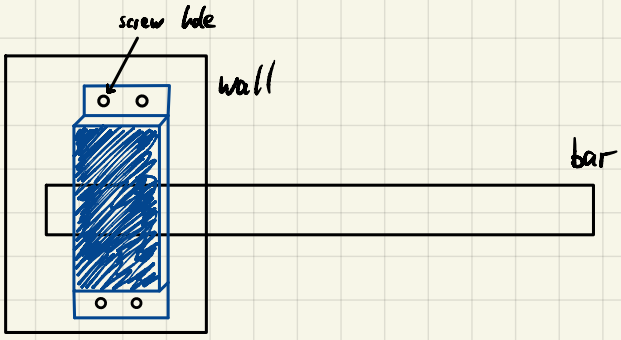
↳ too little space at top to fit bar and still be able to open window

=> may work, but too complex (as too tight) for the intended complexity of this design

option 2: bar above window box ✓

holder

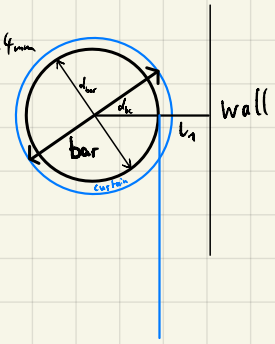




Spacing to wall

$d_{bar} = 28,8\,mm / r_{bar} = 14,4\,mm$

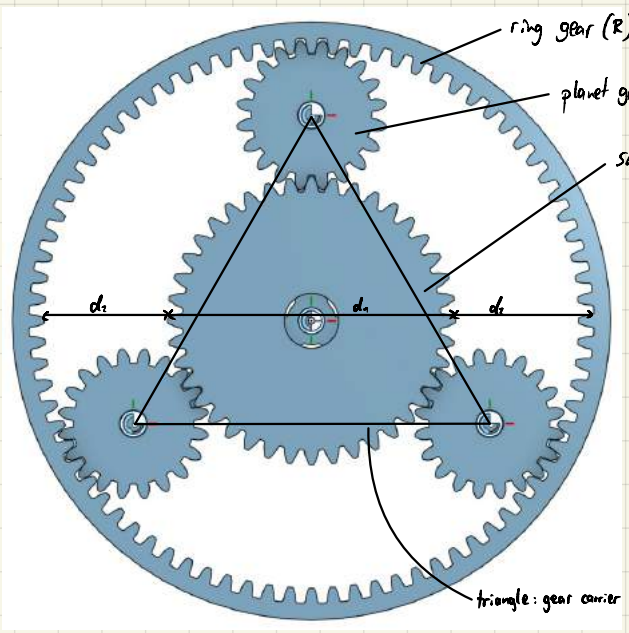
d_{bc} from 43mm to 67 mm



$L_1 = \frac{67mm}{2} + 10\,mm = 43,5mm$

$L_1 = \frac{43mm}{2} + 22\,mm = 43,5mm$

gearbox



X_z ... number of teeth on gear X

calculate R_z from P_z and S_z

$m = \frac{d}{z}$

P = 9 / d = 4,5 / d = 0,75
S = 12 / d = 6 / d = 1

$m = \frac{d_1}{S_z}$ → $m = \frac{d_1 + 2d_2}{R_z}$ → $R_z = \frac{d_1 + 2d_2}{m} = \frac{(d_1 + 2d_2)\cdot S_z}{d_1} = \frac{S_z d_1 + 2 S_z d_2}{d_1}$

use: $d_1 = 1$

$d_2 = \left(\frac{d_1}{S_z}\right)\cdot P_z = \left(\frac{1}{S_z}\right)\cdot P_z = \frac{P_z}{S_z}$

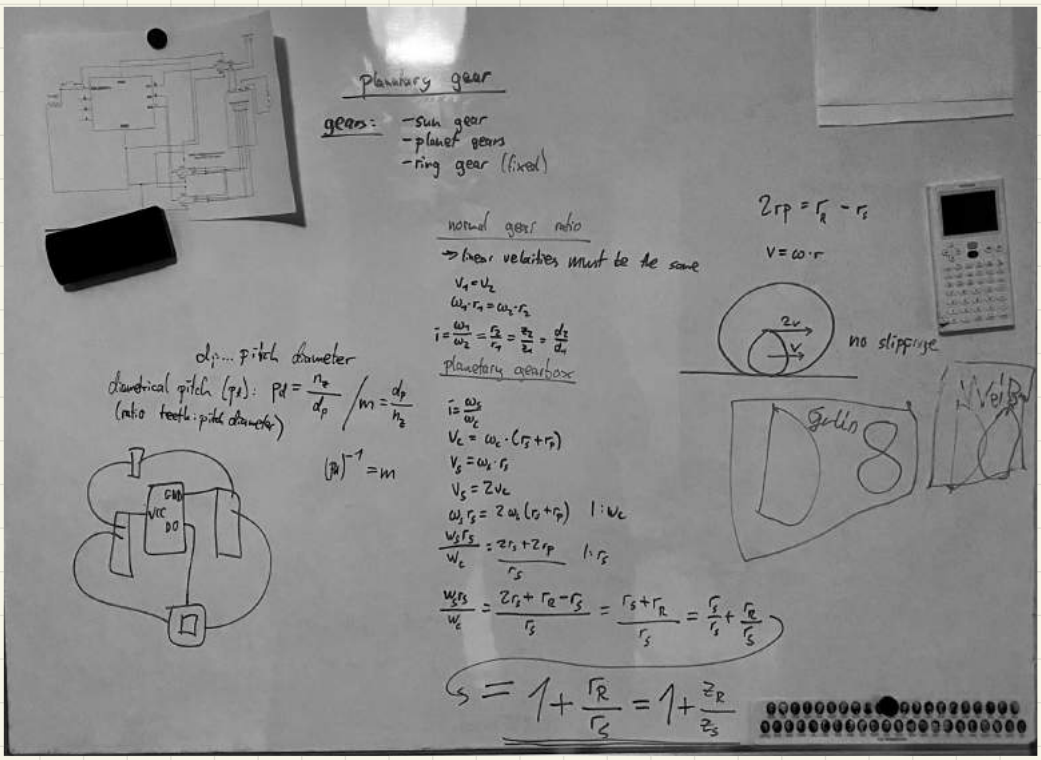
$R_z = S_z + 2S_z \cdot \underbrace{\left(\left(\frac{1}{S_z}\right)\cdot P_z\right)}_{d_2}$

Vereinfachung:

$R_z = S_z + \frac{2S_z \cdot P_z}{S_z} = S_z + 2P_z = R_z$

$P_z = \frac{R_z}{z} - \frac{S_z}{z}$ $\quad S_z = R_z - 2P_z$

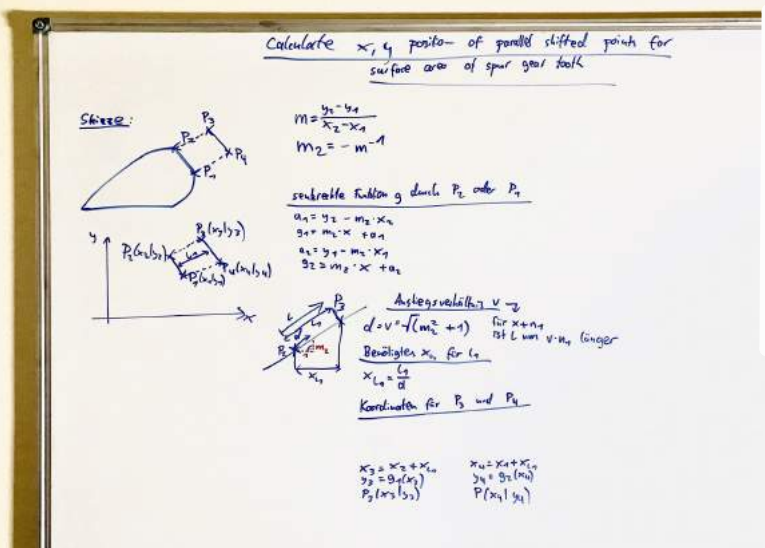
calculate gear ratio of planetary gear (ring gear fixed)



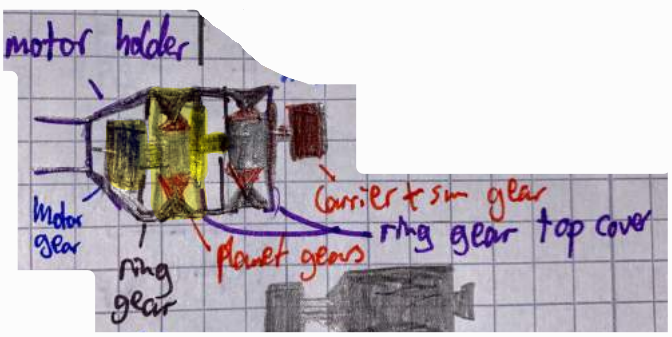
tooth profile

→ using herringbone gears

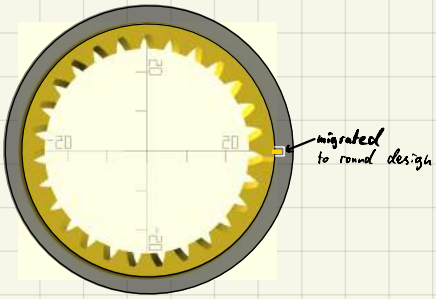
calculate gear tooth polygon with extended surface



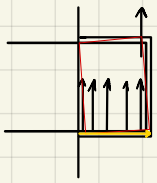
parts



ring gear + ring gear holder



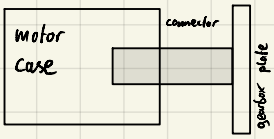
✗ fixing interaction:



✓ fixing interaction:

- better power transmission → can't break as easy
- still stable enough to fullfil purpose

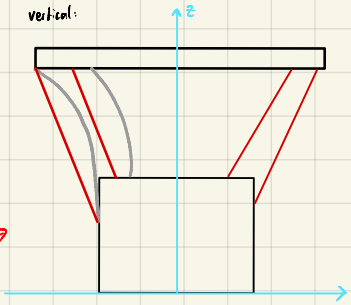
motor mount



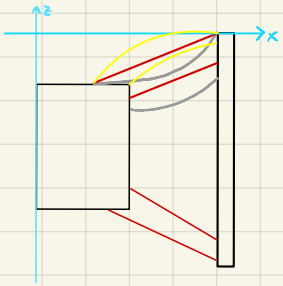
None of these design ideas were used, instead a different improved design was implemented.

connector 2D design:

vertical:

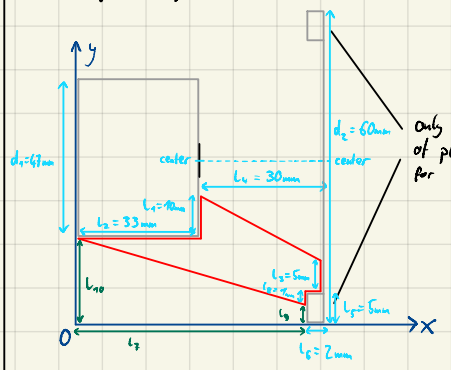


horizontal:



A straight connector is used to save time designing a rounded connector.
The shown gray design is good for both vertical directions (+ mirrored at the x-axis), but not very ideal in horizontal direction (+ mirrored at x-axis). For horizontal direction a design with the roundness directed to the outside is (probably) more ideal (somewhat like the yellow design).

straight design: ✗ not used eventually



Only showing parts of plate relevant for the connector

● : computed
● : given

Calculations

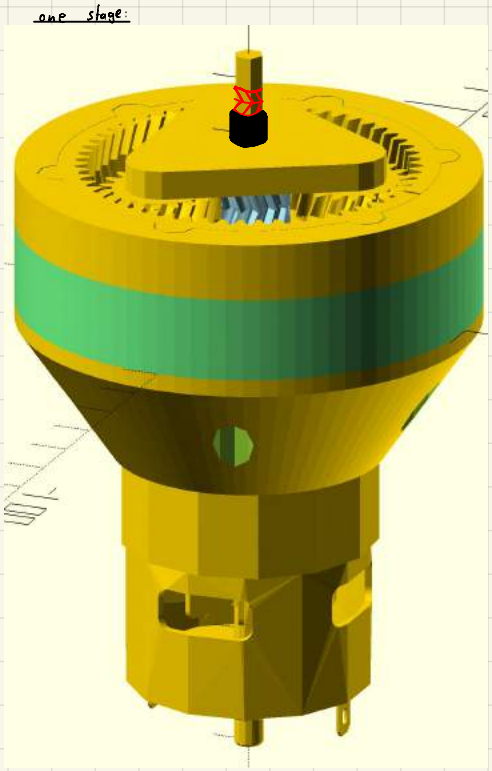
$L_7 = L_2 + L_4 - L_6 = 61\,mm$

$L_9 = L_5 - L_8 = 4\,mm$

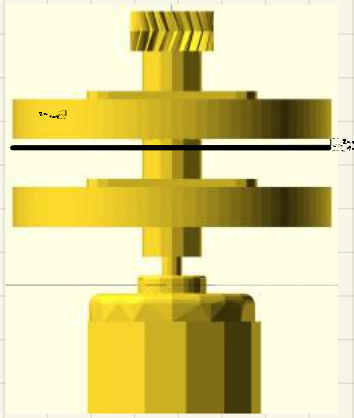
$L_{10} = \frac{d_2}{2} - \frac{d_1}{2} = 6{,}5\,mm$

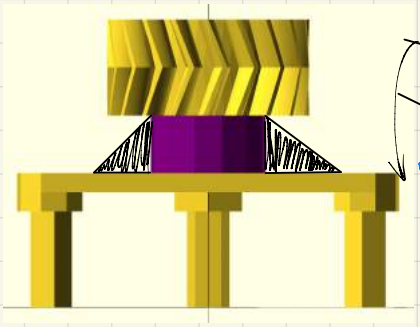
first and successive stages

one stage:



two stages:





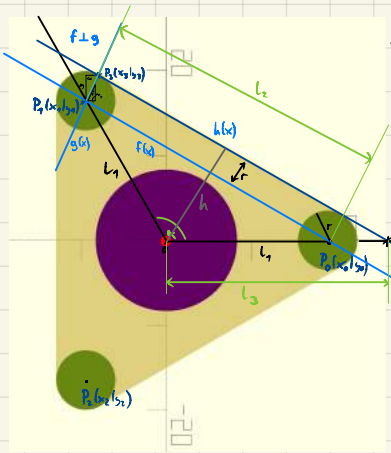
wanted direction (roll up)
direction due to gravity (roll down)

if the difference between the blue force and the black force is too great, the bonding forces between the atoms can't withstand the force difference and the gear base seperates from the carrier base. To allow a greater force difference a bigger contact surface between gear base and carrier base is needed. To implement this a cone-like shape is used.

↓ total bs

✗ Instead of breaking at the base, the gear could now break at the gear base. Thus the cone-like support is unnecessary and was discarded.

Calculate minimum distance to carrier border h

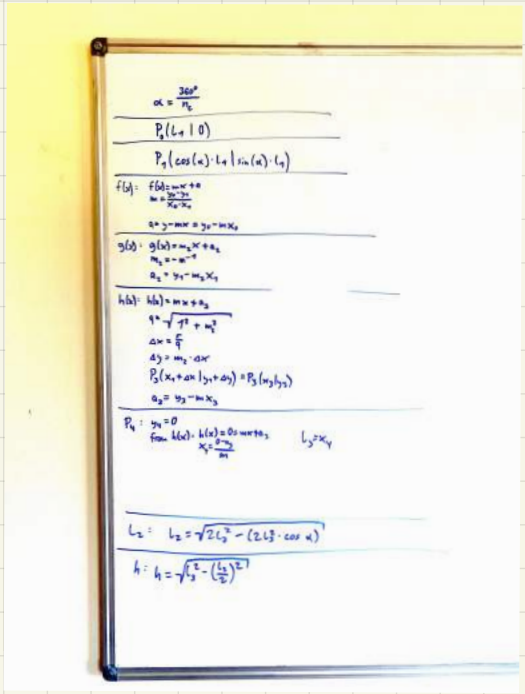


→ each green circle must have the same radius and the same offset

L_1 ... distance from (0|0) to $P_{0=3}(x_{0=3}|y_{0=3})$ (offset)

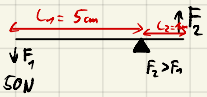
n_c ... number of circles which are the boundary of the carrier base slope

→ Calculations for h



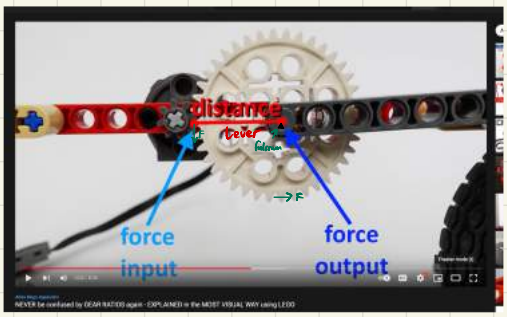
→ For visual representation see GeoGebra at
https://www.geogebra.org/classic/dtjbpaw2

Torque increse with speed decrease



$L_1 \cdot F_1 = L_2 \cdot F_2$

50N · 0,05m = 2,5Nm → $\frac{2,5Nm}{0,01m}$ = 250 N



Is the planetary gear self-locking?

→ too many variables to be able to calculate or even estimate an answer

→ solution: print and test it, if it isn't self locking a worm gear can be added without reprinting the main parts

3D-printer calibration

with help of 20mm x 20mm x 19,91mm calibration cube

x-axis ✓	y-axis ✗	z axis ✗
	- 20,15mm → 20,10mm	19,75mm
	- 20,16mm → 20,11mm	19,71mm
	- 20,16mm → 20,11mm	19,77 mm
	- 20,15mm → 20,10mm	19,76 mm
	Ø = 20,155mm → 20,105 mm	19,73 mm
	→ caliper has ± 0,05mm	ø 19,744 mm
	as I preferably want a positive difference in length from the 20mm, than a negative difference I'll subtract 0,05mm from the measured ads	$\frac{19,744mm}{19,91mm}$ = 99,166%
	20,105mm − 0,105mm = Δl	current: 0,002500 $\frac{mm}{step}$
	→ can only change steps per mm for x and y motors together	new: 0,002479
	↳ currently: x-20mm, y-0,105mm inaccuracy : 2	
	↳ after calibration x- 0,0525mm, y- 0,0525mm inaccuracy	
	currently: 0,010611 $\frac{mm}{step}$	$\frac{20,0525mm}{20mm}$ = 100,2625%
	new: 0,010639 $\frac{mm}{step}$	·0,010611 $\frac{mm}{step}$

Motor

- 775 DC brushless motor

mounting screw size: M4

operating voltage for application: 5V

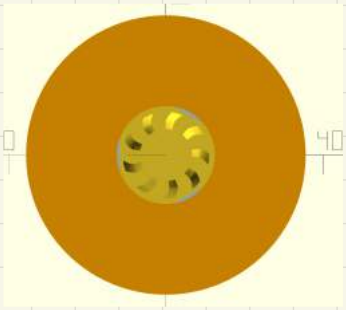
RPM for 5V: see spreadsheet

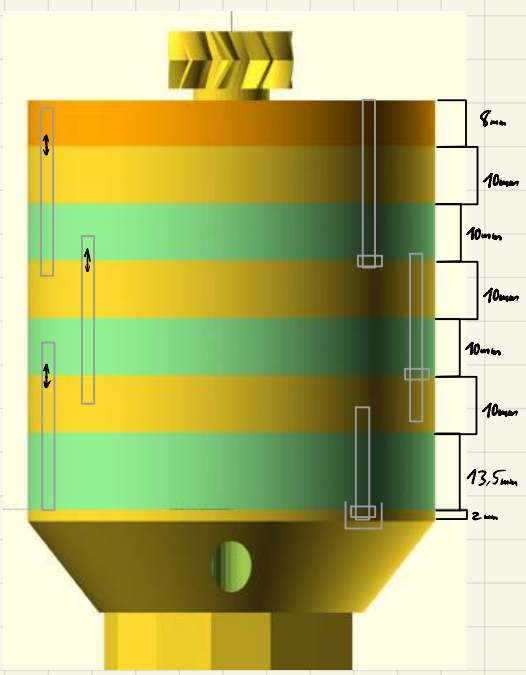
Bolt

→ To connect the different components bolts and nuts are used

Size: M5

Lengths available: 20mm, 30mm, 50mm, 60mm
↓ ↓ ↓ ↓
18x 40x 14x 4x





Bolt - Algorithm

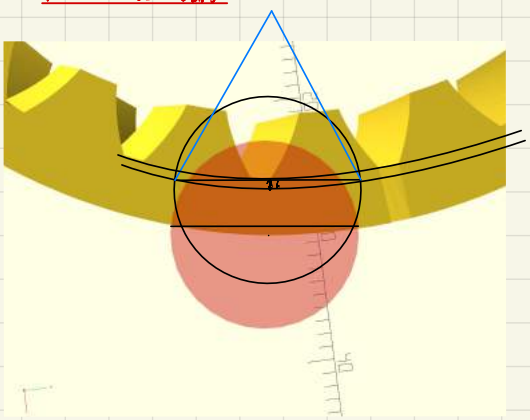
tasks: - output y-coordinate of bolts and nuts with bolt column (0 or 1)

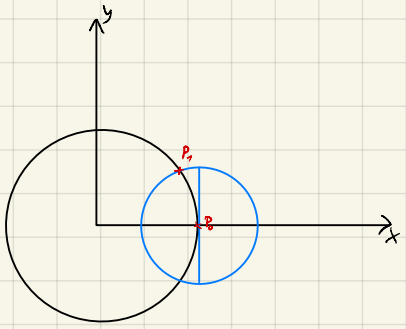
→ new design: ← no nuts, just bolts

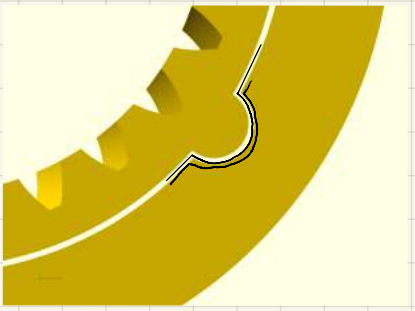
Possible positions of nut:

- inside, at top, at bottom of stage
  - ↳ clerk at least 3mm thickness to top and 1,5 mm thickness to bottom
  - ↳ if not enough space, go one stage up
  - ↳ place nut at top of stage as max. possible by constraints
- between two stages
  - ↳ place nut in upper stage

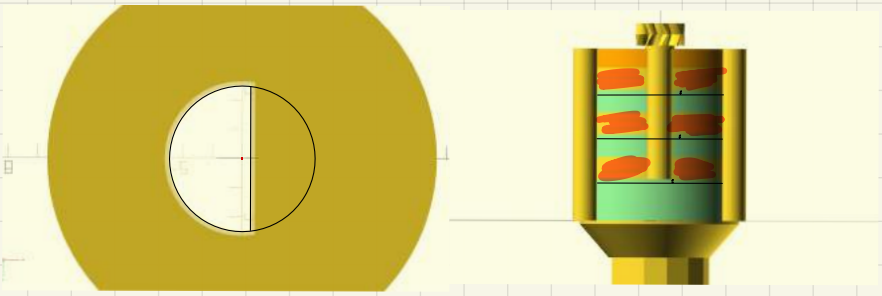
Motor case mounts





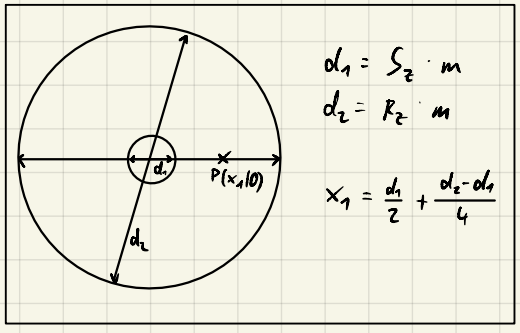


Motor gear mount shape



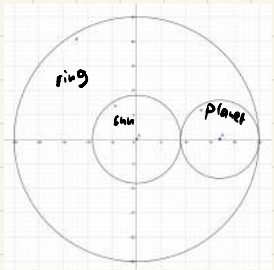
The half-circle motor shaft prevents slippage of the shaft inside the shaft/motor gear. With a normal circle the shaft could turn without the gear turning, which is obviously not wanted.

calculate position of planet gear



$$d_1 = S_z \cdot m$$
$$d_2 = P_z \cdot m$$
$$x_1 = \frac{d_1}{2} + \frac{d_2 - d_1}{4}$$

picture of pitch diameters



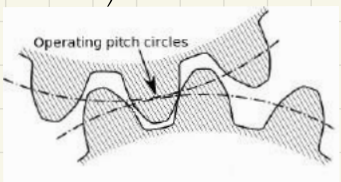
alternative

z ... number of teeth
m ... module
p ... pitch diameter

$$x = \frac{P_s}{2} + \frac{P_p}{2}$$
$$x = \frac{m_s \cdot n_s}{2} + \frac{m_p \cdot n_p}{2}$$

How pitch circles (pitch diameters) should align for gears to mesh

B(x|0)



Problem: non-smooth movement of planet gears, motor gear and carrier

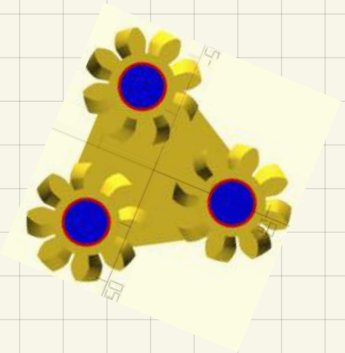
Why: The issue comes from a wrong configuration of the teeth numbers of the gears. Current configuration is $t_s = 9$, $t_p = 8$, $t_R = 25$. Those amounts don't violate the $t_s = t_R - 2t_p$ formula. If we only had one planet gear the gears would mesh perfectly fine. The issue arises when using more than one planet gear. When aligning three planets at 120° increments there is no way all planets will be able to mesh with the sun and/or ring gear at their specific position. The 0°/360° planet will mesh, but the other two won't be able to mesh if positioned at 120° or 240°. What happens is that they move to a position greater or smaller than 120°/240°. Due to this movement the carrier bars won't be in the middle of their planet gears anymore. This leads to intense friction between planet hole and carrier bar. Following is a non-smooth motion when rotating. This also explains why a increase in tolerance helps, although it doesn't fix the actual problem.

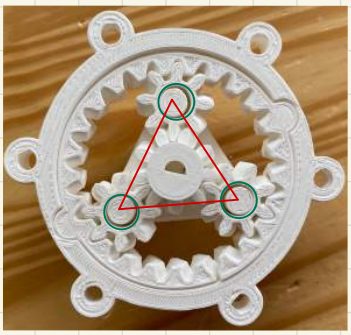
Steps when choosing tooth numbers for gears

Steps are generalized as far as is necessary for this project, they probably could be generalized even more.

1. Choose sun gear teeth number t_S. t_S must be able to be divided by the amount of planet gears (commonly 3) without rest.
2. Choose ring gear teeth number t_R. t_R must be a multiple of t_S. t_R must also be selected that the planet teeth amount t_P is a whole number when computing after $t_P = \frac{t_R}{2} - \frac{t_S}{2}$
3. Planet teeth amount is $t_P = \frac{t_R}{2} - \frac{t_S}{2}$.

→ Done





↳ That's just half of the solution:

Above makes the movement better, but the movement isn't completely smooth yet.

Perfect shape:

Stretched shape: (↙ wider)

Compressed shape:

The ring gear also causes problems

- Can't improve much by design. Solution concentrates on post-processing steps after printing.

Issue is the shape of the ring gear. Due to it's flexibility it can change from the CAD shape easily. Due to this deformation the teeth of the planet gears don't align with the teeth of the ring gear perfectly. This produces friction and a force develops which tries to push the ring gear into the right shape.

Solution:

Stretch the ring gear like showed on the photo before assembling the stage. When embedded into the ring gear case the ring gear will try to take all the space it gets, eliminating spacing as much as possible.

Additionally, a slightly bigger spacing than necessary needed between ring gear and ring gear case should be configured in the CAD (~0,5 mm). This spacing isn't allowed to be too big though, as this just like before would cause problems with the planets beeing able to mesh with the ring gear.

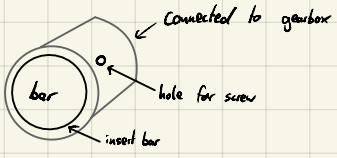
Gearbox - bar connector

- relatively high torque → should hold even at high torques

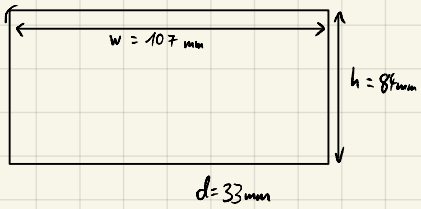
bar:

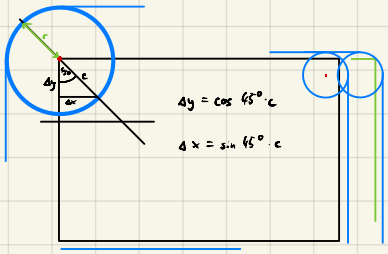
$d_{bar} = 28,8\,mm$

connector:



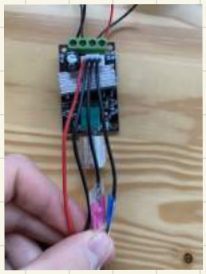
Electronics box





electronics

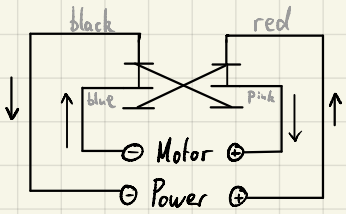
DPDT switch wiring



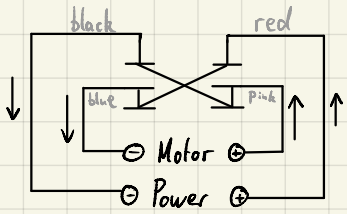
Functions:
- toggle motor
- switch motor direction
- be able to set voltag of motor (manually)
- if button pressed, toggle motor

switch type: double pole, double throw (DPDT) with On, On, Off switch

On I:



On II:



regenerative braking (braking mode):