Windmill Project

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Section 006
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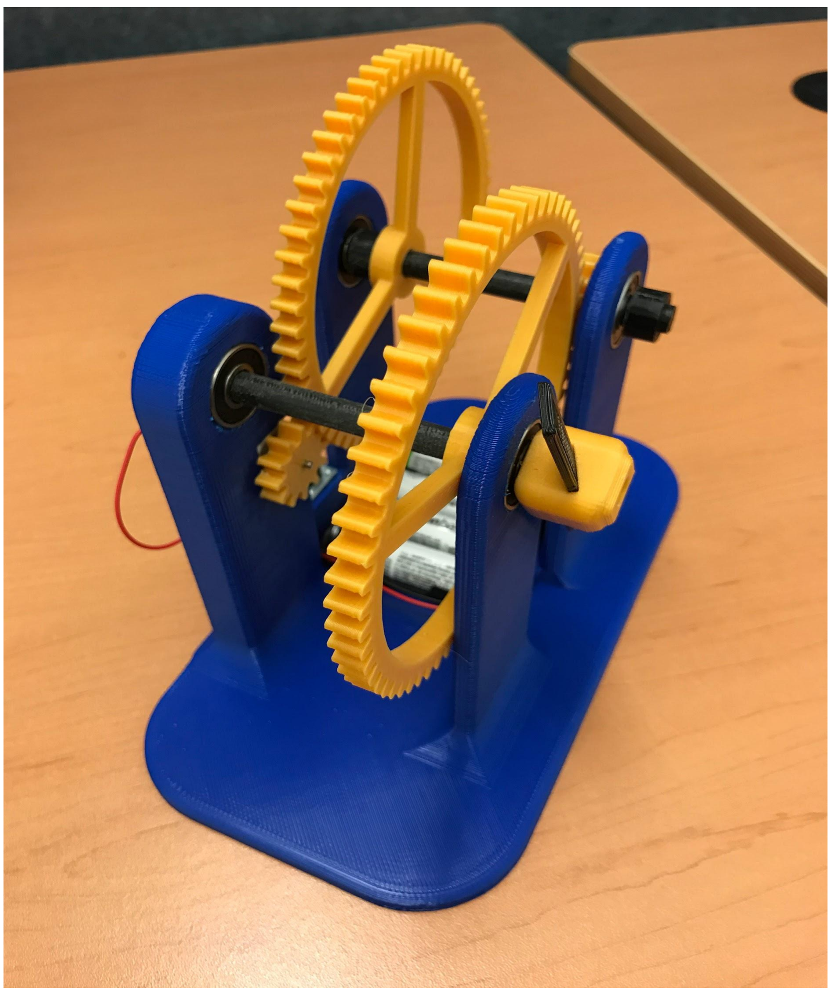


I. Background and Intro

a. Relevant info specific to this design

In this project, we will assemble a wind turbine with the knowledge we learned from ME354 and apply the knowledge to our prototype. Our prototype will be assembled by several main components such as, a gear box made from 3D print, a motor given by the instructor, two shafts made from 3D print, 2 small gears from 3D print, 2 big gears from 3D print, 4 bearings given by the instructor, 4 batteries bought from online store, a battery holder bought from online store, and two fan blades from 3D print. Our main idea about this design is to use several gears to reduce the speed of the motor shaft and transfer this power to run the fan blades. The theory of gear ratio is applied in our problem. The speed of gear will be transferred to another gear depending on the gear ratio between these two gears, the formula of gear ratio is transferred gear divided by transferring gear. And the gears can be connected in any methods, the method we chose is direct connecting with the application of direct path theory. We will connect our last transferred gear to our fan blades with the help of a shaft. The shaft's rotating speed is based on the speed of the gears connected. The fan blades' speed is based on the same shaft connected. When all the parts are connected properly, the motor is able to run the wind turbine.

b. Literature supporting design

Referred to Exploring Engineering (Third Edition), Gear Ratio. Gear ratio is extremely important in mechanical systems, including its impact on speed, torque, and power transmission. Gear ratio is depending on its number of teeth on each gear connected. Different gears have different applications. The gear type we chose is spur gear, spur gear is great with simplicity, efficiency, and versatility. It can transfer power with little loss. It is also easy to draw in CAD and manufactured. And spur gears have a wide range of applications. It can be used in any position in our prototype.

II. Design Process and Justification

A. Design Process

The design process starts with several questions. What's the gear ratio? How many gears do we want? What are the design creterias? What should be the configuration of the design?

We started with the size of the gear box and the gears. Then we find the gear ratio and number of teeth. With some geometry involved, we built a MATLAB code (See Appendix) to calculate the number of teeth based on the gear ratio. Next, we determined the dimensions of the gear box, including the space for the battery box, switch, and motors. Then we use Seimens NX12 to construct the gears and printed them in the 3D printing Lab in the ME building. All the parts have built-in clearance because of the printer.

B. Final Design

Final design becomes what's shown in the picture on the title page. This design is simple and easy to build. It just needs two shafts and four gears. Other than soldering, we just need to push the bearings, the switch, and the motor into the openings, and it has a good press fit in those places. A battery box will provide power to the motor, the motor will rotate the small gear, and the small gear will drive the large gear. This large gear is connected to a shaft which will drive another small gear. This small gear will drive another large gear and to the blade.

C. Results

The design works as we expected. The motors, gears, and shafts rotate at a decent speed. There is some noise from it because the teeth are punching by the re-acceleration of the motor. It can start the system by itself after switching it to on and a hand push is not needed. The position of the shafts is perfect. The gears are not too close or too far away from each other. The position of the motor is also in the right place. It's secured in its seat and secured by a small plate. Everything works perfectly. During the demo, it just works as fine as the testing. Other than the noise, everything works smoothly.

D. Gear Design

We started the gear design with some Youtube videos talking about the dimensions of the gears, such as the pitch circle, root circle, etc. Then based on the maximum size of the gearbox and the original design, we can derive a relation between the gear ratio and the number of teeth. It becomes two unknowns and two equations. One equation (eq.1) is that the sum of three large gear radii and one small gear radius is less than the maximum width of the gearbox.

$$3R + r \leq W_{max} \quad \text{(eq. 1)}$$

The second equation (eq.2) is the gear ratio. It's the ratio of the number of teeth or the ratio of the radius of the pitch circle.

$$R/r = N/n = GR \quad \text{(eq. 2)}$$

After some calculations, we check if the printer can print the teeth in such size. Since the dimensions are calculated, they worked very well. The tips of the teeth are not touching the root circle of their adjacent gears.

Finally, we decided to use gear ratio of 5, and number of teeth on the small gear is 12. More dimensions and picture of the gears are in the appendix (See Appendix).

E. Blade Design
We decided to make them into three parts. Two parts are the blade, and one is the centerpiece which will connect the blade to the shaft. We built them in this way because it‘s easy to assemble them together. The blades are thin Rectangular cuboids with thickness of 2 mm. The connecting part has a round hole for the shaft from top to bottom, and two rectangular holes for the blade on the two sides. With some built in clearance in the parts, the blades are secured by pushing them into the centerpiece without using the super glue. The cener piece is pushed onto the shaft without slipping or free spinning. Although it’s barely making some wind when it’s running, the whole blade didn’t fell apart.

F. Shaft and Housing Design
The shaft diameter is determined by the inner diameter of the given bearings. The outer diameter of the bearings determined the size of opening on the gearbox for the bearing to sit. The distance between the stands are determined by the pitch circle of the gears, so the gears won’t be too loose or too tight. To determine the position of the motor, we set a certain distance from the gear and see at which angle it can fit into the stand with some clearance for the key (See Appendix, Gearbox).

III. Conclusions and Improvements

A. Compare to other teams

Our design is relatively smaller and simpler when compared to the commercial turbine. Our turbine explained the basic idea of a commercial turbine. Both our prototype and commercial turbine have power sources, shafts, and gears fixed and connected. However, the commercial one has a more fancy and more precise design. During the lab, we also compared our design to other teams. The most impressed design will be the first team, who get a really low speed of fan blade with such a small box. They have two shafts connected to all the gears. All the gears are connected by a small gear and a large gear with the same size. The gears connected and created a large gear ratio to reach a low speed of the fan blade. They utilize the space pretty well. Our design is similar to 60% of teams. We both connect one gear to one shaft and connect the gears. The cons of this design is the space is limited and we can not reach a low speed. 40% of teams use the design like the one we mentioned before, two shafts with all the gears connected. The pros of this design is it can reach a relatively low speed and adjust the speed by adding and reducing the number of gears on the shaft.

B. Future Improvements

We try to improve our design on both aesthetic and performance. In order to make our design pleasing to the eye, we can try to have more design on the gear box and hide the wires connected to the great box inside the new-designed gear box. From the perspective of performance, we can add more gears to have a larger gear ratio, we can make our gears on the shaft flexible and add more gears to the same shaft with the same size. This approach is pretty similar to the design of other groups. Another improvement on the performance is changing the voltage of the power supply from constant to adjusted. With an adjusted power supply, we can control the speed of the fan blade via controlling the voltage of the power supply. Both the speed can be lower and the energy can be saved.

C. Application of Concepts

The concepts we applied are metal removal principle, direct path principle, gear ratio, and clearance fits. Firstly, we remove larger percent material from the gears to improve the efficiency of the gears without buckling. Referring to our design, our gears are almost “hollow” with only three bars connected. It can help save material and lighten the total weight of the gearbox. The second concept we applied is the direct path principle from the shape synthesis. Our gears are made in the same width in order to fully contact. With the help of fully contacting, the bending between two gears can be minimized. We also apply the idea of gear ratio in the first lab, we can adjust the number of teeth on the gears to change the gear ratio. The efficiency of gears is depending on the number of teeth rather than the size of the gears. And the size of the gears can improve the limitation for the number of teeth. We try to maximize the number of teeth on our bigger size of gear in order to get a larger gear ratio. We also applied the concept of clearance fits in our design for the connection between the shaft and the gears. We make the diameter of the shafts and inner diameter of the gears almost the same size to reach the clearance fit. Clearance fit can help us fix our gears to the shaft.

D. Biggest Takeaway

Our biggest takeaway from the project will be the application of the engineering design concept to real world problems. We utilize what we learned in the lecture and labs to create a runnable wind turbine. And the utilization of CAD can help us improve our familiarity with this tool. Since we will be using CAD a lot of times as an engineer in the future, familiarity can help us work more efficiently later. All the steps from designing, processing, and evaluating can help us practice and improve our engineering ability.

IV. Reference

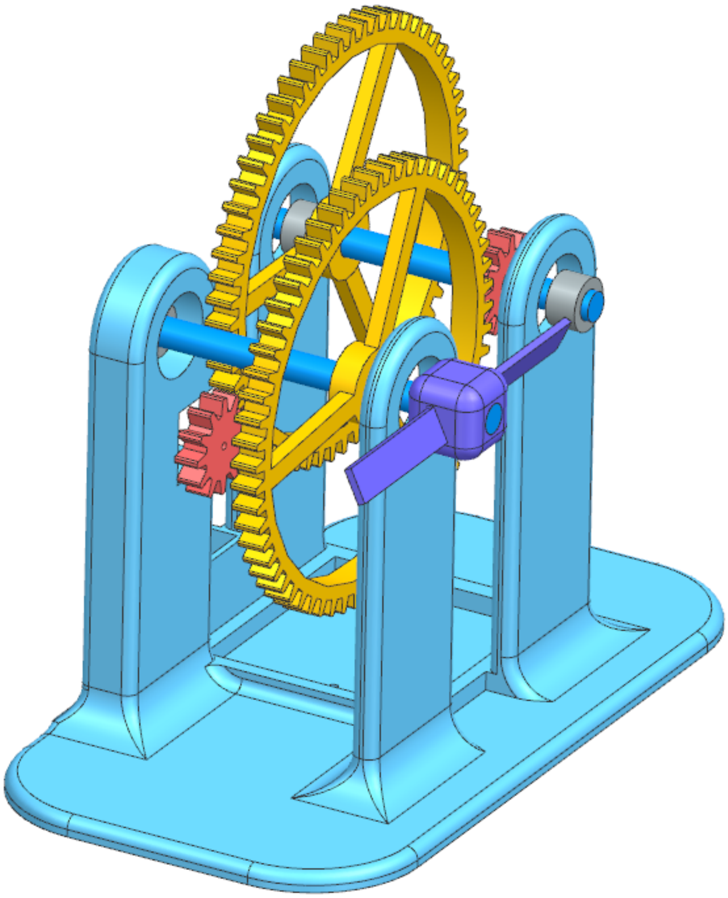
1. Philip Kosky, Robert Balmer, William Keat, George Wise. Gear Ratio. In ScienceDirect Topics. Retrieved April 6, 2023, from https://www.sciencedirect.com/topics/engineering/gear-ratio

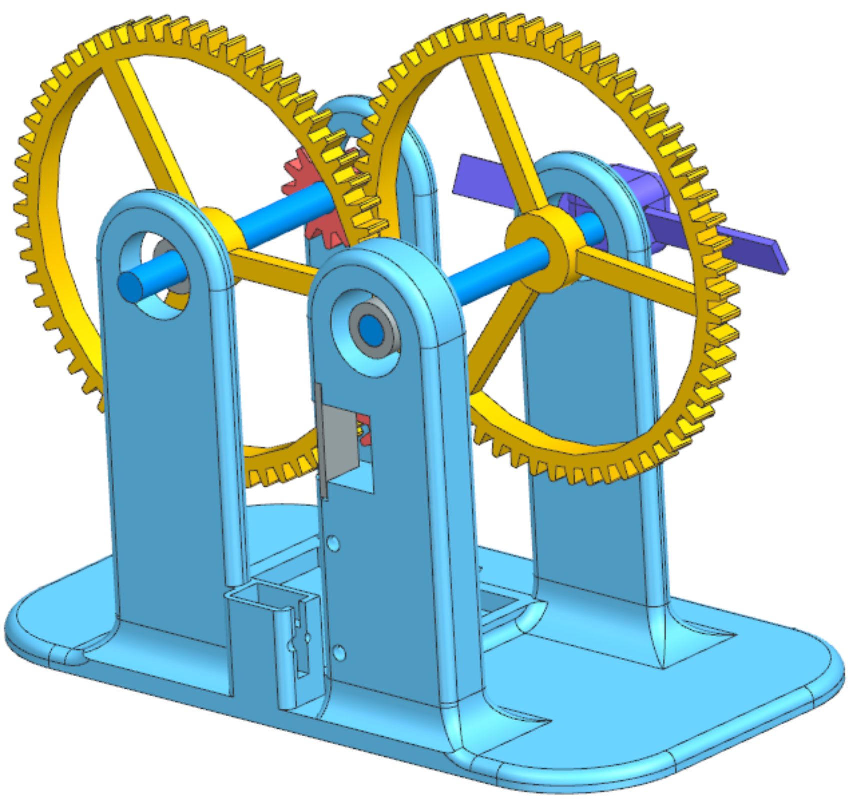
2. https://www.youtube.com/watch?v=IBcGLpQnfYk

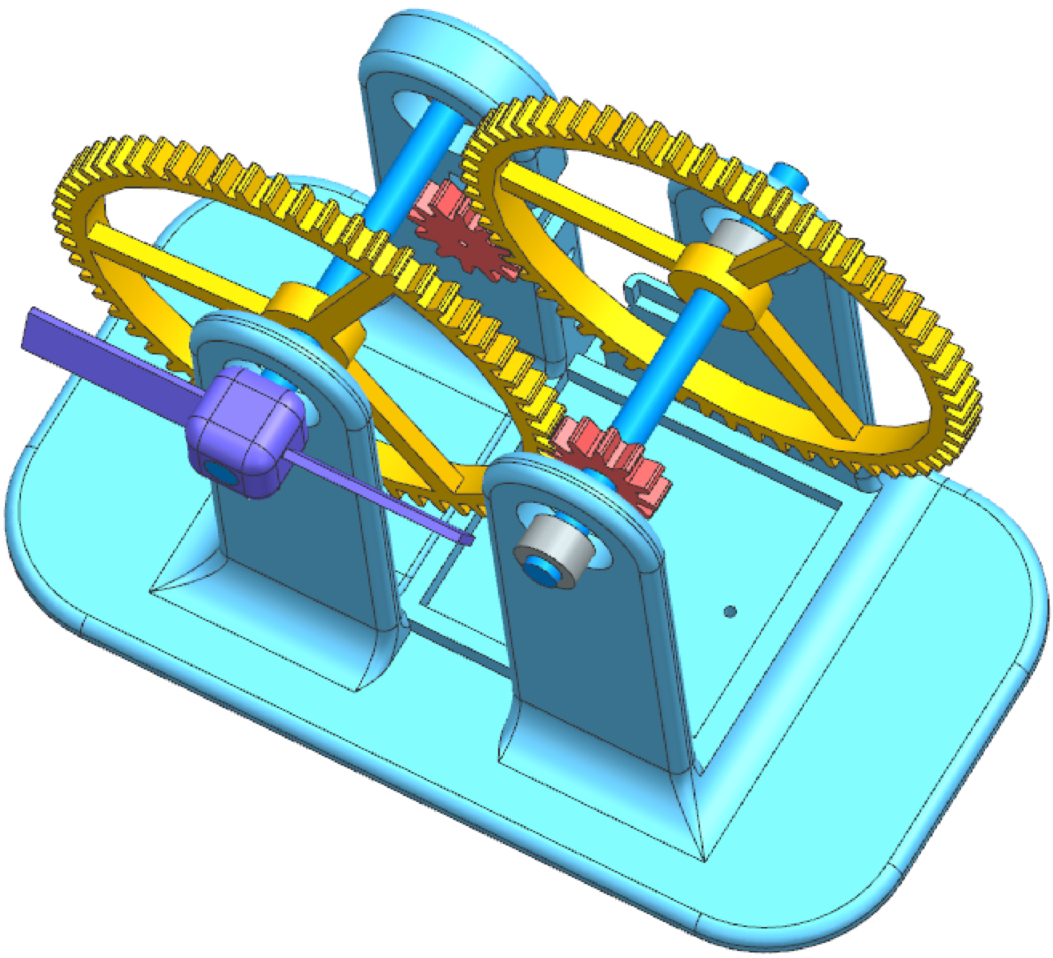
V. Appendix

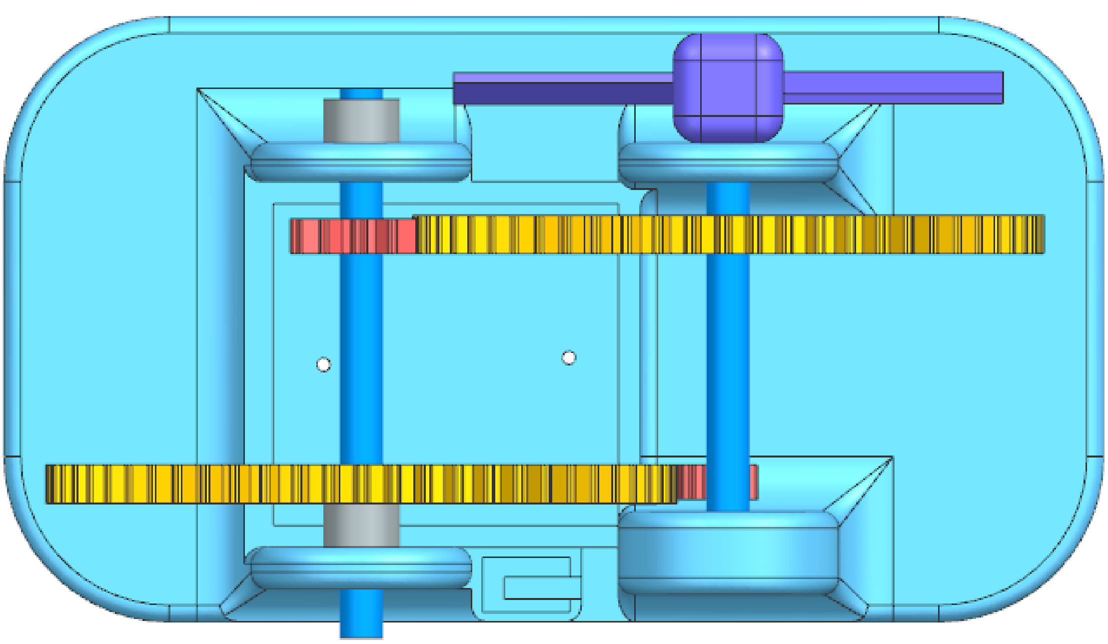
A. General Design

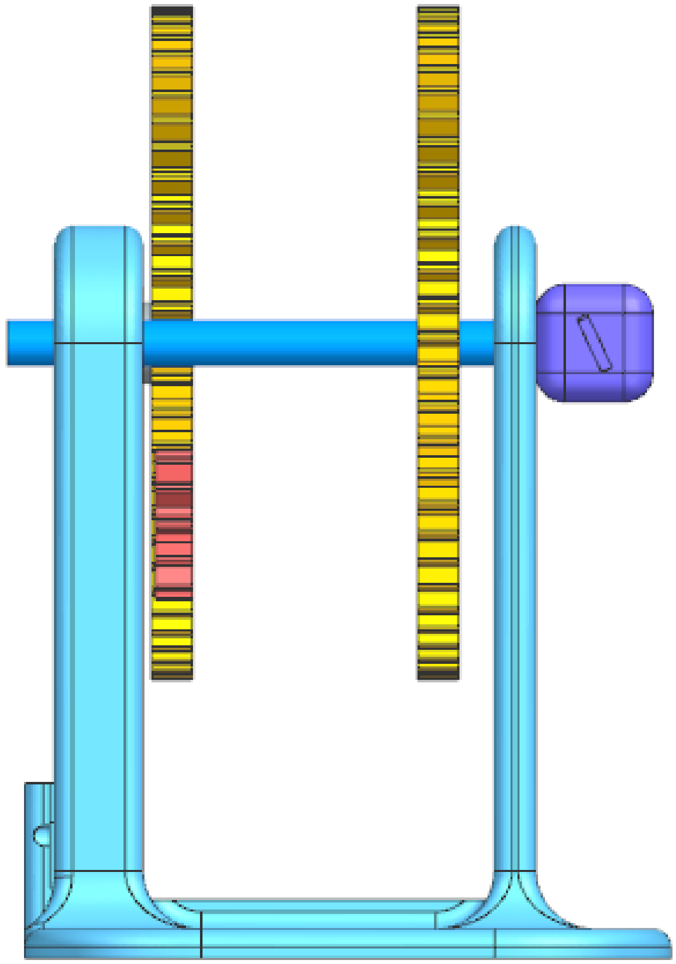
a. CAD Assembly

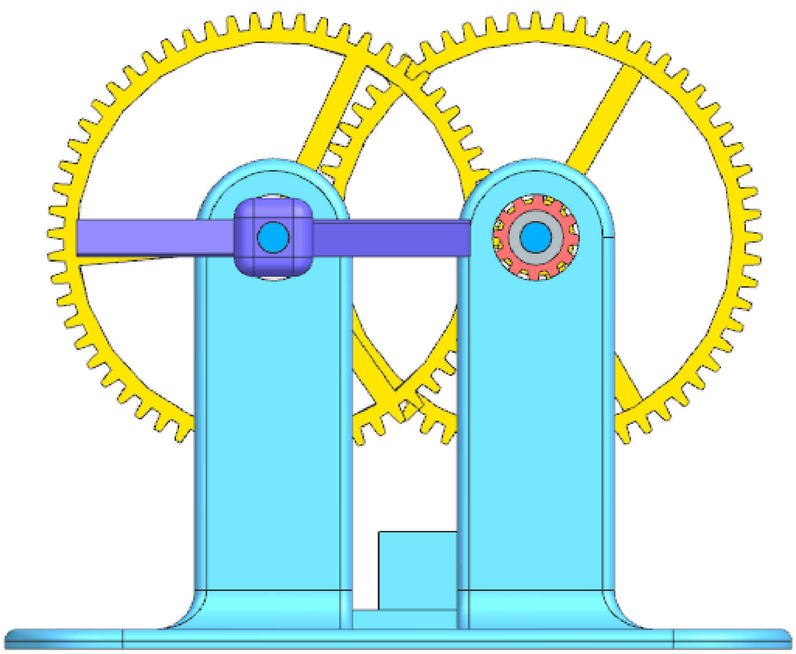




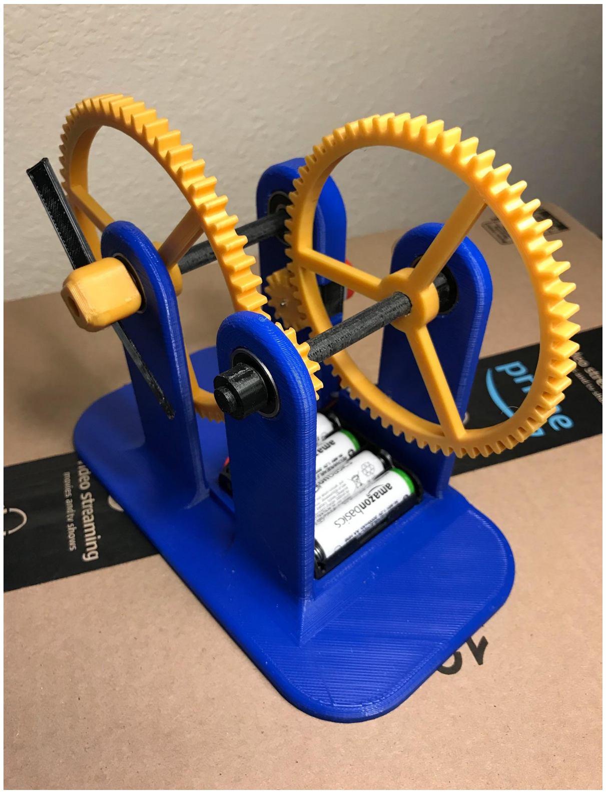


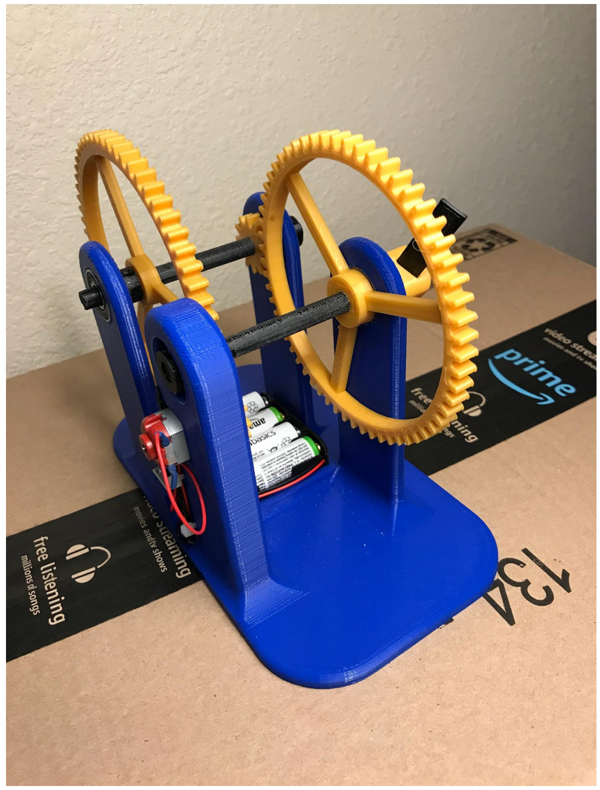


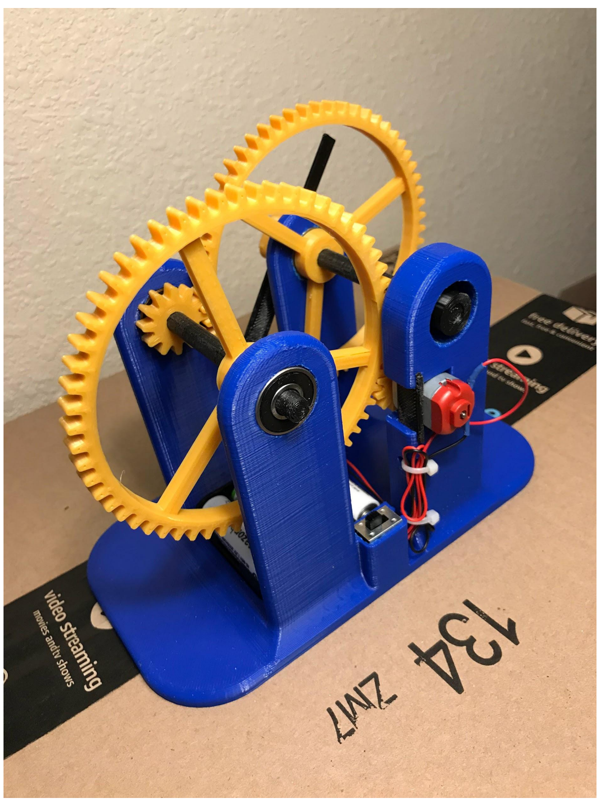


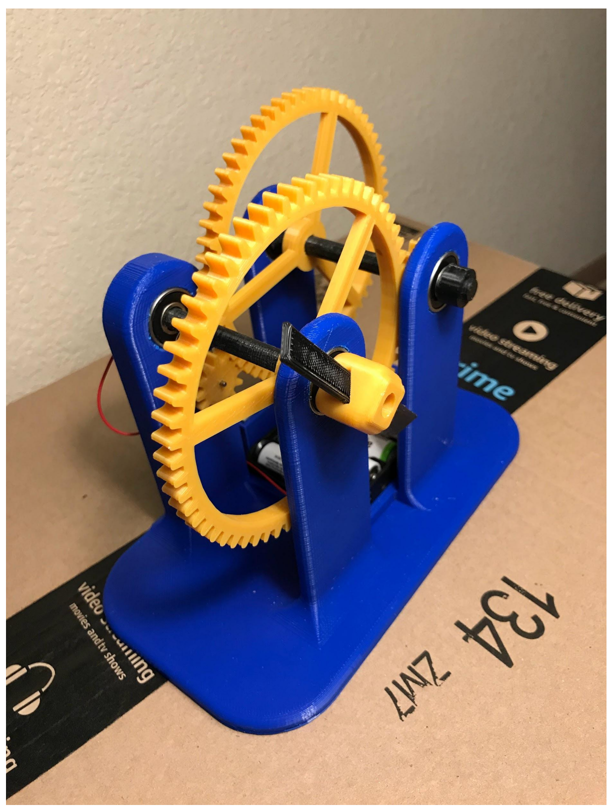


b. Final Assembly









B. Gear Design

a. Gear Calculation

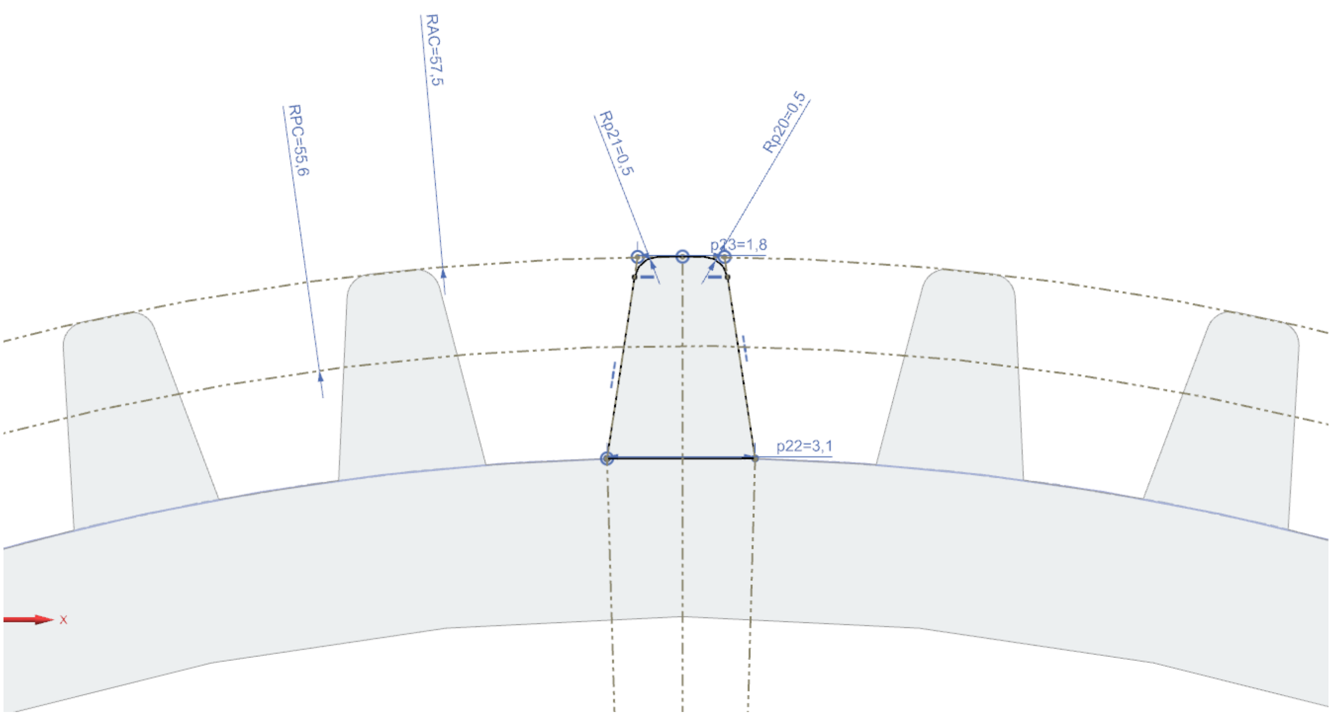
i. MATLAB Code calculation

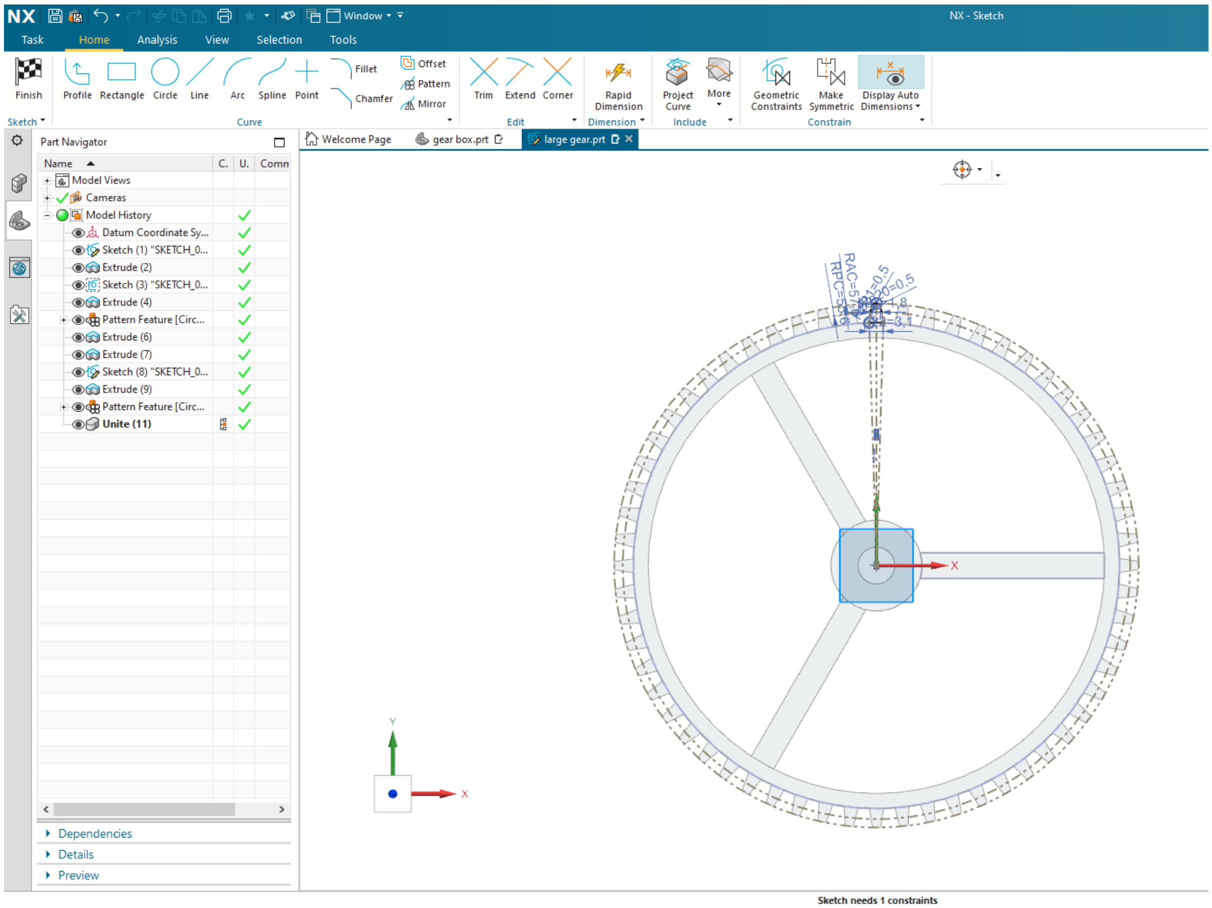
```
clear
clc
close all

%% info
% All in mm
% Reference: https://www.youtube.com/watch?v=IBcGLpQnfYk
% gr: gear ratio,R/r
% n: number of teeth
% pc: pitch circle, radius
% d: pitch diameter
% cp: circular pitch, arc length
% m: module
% ac: addemdum circle, radius, outer most radius
% de: dedendum
% rc: root circle, radius
% wd: whole depth of the tooth profile
% cc: clearance circle, radius
% bc: base circle radius
% pa: pressure angle, deg
% In to Out: rc, cc, bc, ac
%% general info
gr=5; %gear ratio, R/r
total_width=178; %mm, tota width of 3R+r
n_small=12; %number of teeth, small gear
%% small gear
pa=15; % pressure angle, deg
pc=total_width/(3*gr+1); %pitch radius
cp=2*pi*pc/n_small; % circular pitch, circonference / number of teeth

m=cp/pi; % module, addendum
ac=pc+m; %addemdum circle, outter most radius;
cc=pc-m; % clearance circle


de=1.25*m; % dedendum
rc=pc-de; %root circle, at bottom land

wd=m+de; %whole depth

bc=pc*cosd(pa); %base circle, radius

rank_small=sort([pc,ac,cc,rc,bc]);
%root circle, clearance circle, base circle, pitch circle, addemdum circle
% rc, cc, bc, pc, ac
%% large gear
n_large=gr*n_small; %number of teeth
PA=15; % pressure angle, deg
PC=total_width/(3+1/gr); %pitch radius
CP=2*pi*PC/n_large; % circular pitch, circonference / number of teeth

M=CP/pi; % module, addendum
AC=PC+M; %addemdum circle, outter most radius;
CC=PC-M; % clearance circle

DE=1.25*M; % dedendum
RC=PC-DE; %root circle, at bottom land

WD=M+DE; %whole depth

BC=PC*cosd(PA); %base circle, radius
```

ii. Gear Calculation Results

AC	57.4792
ac	12.9792
BC	53.7296
bc	10.7459
CC	53.7708
cc	9.2708
CP	5.8250
cp	5.8250
DE	2.3177
de	2.3177
gr	5
M	1.8542
m	1.8542
n_large	60
n_small	12
PA	15
pa	15
PC	55.6250
pc	11.1250
rank_small	[8.8073,9.270..
RC	53.3073
rc	8.8073
total_width	178
WD	4.1719
wd	4.1719

b. Gear Drawings

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NX - Sketch
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Chamfer
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Pattern
Mirror
Trim
Extend
Corner
Rapid Dimension
Project Curve
More
Geometric Constraints
Make Symmetric
Display Auto Dimensions
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Sketch (1) "SKETCH_0...
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Extrude (6)
Extrude (7)
Sketch (8) "SKETCH_0...
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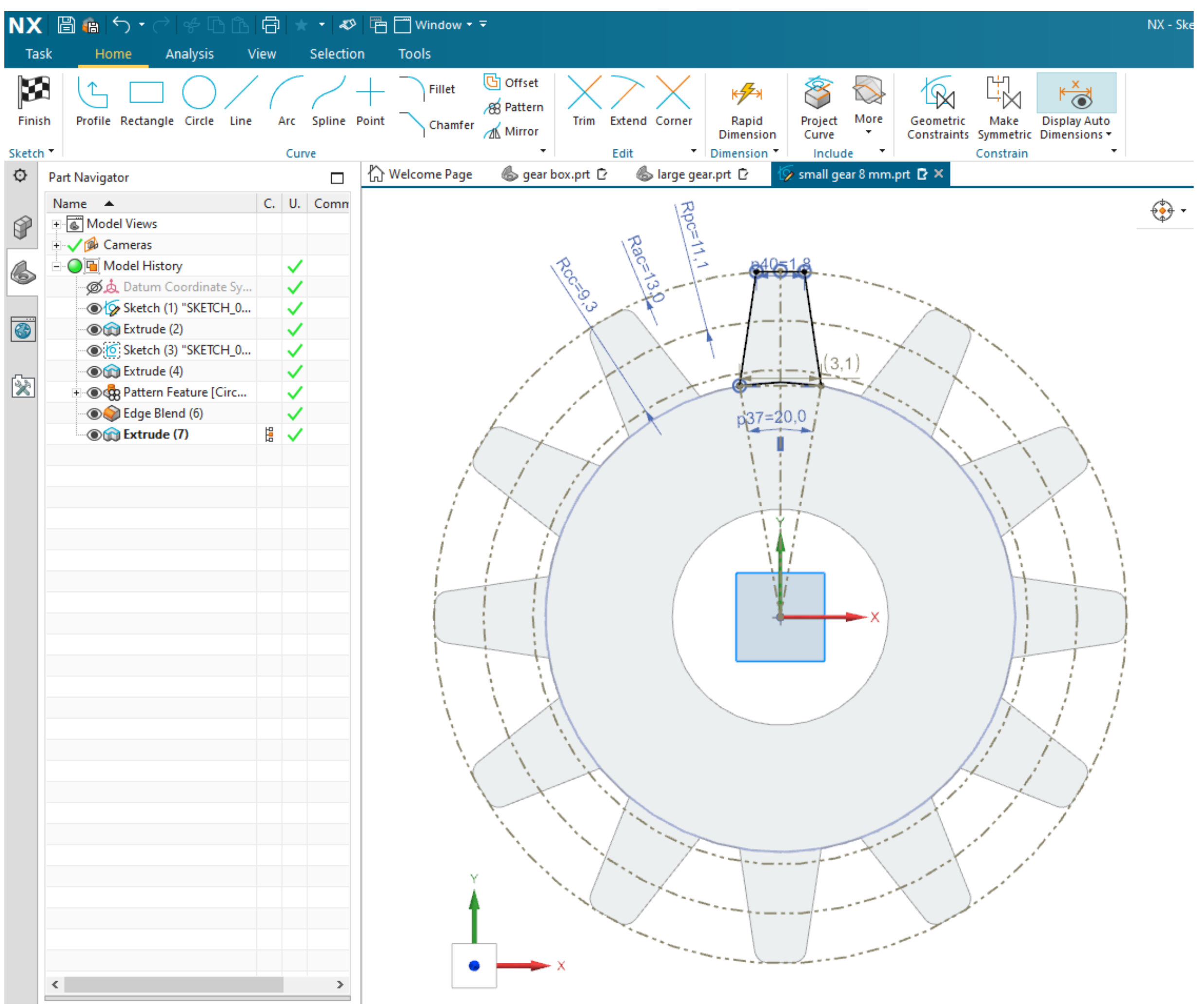
Details
Preview
Welcome Page
gear box.prt
large gear.prt
Sketch needs 1 constraints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More
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Dimension
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Part Navigator
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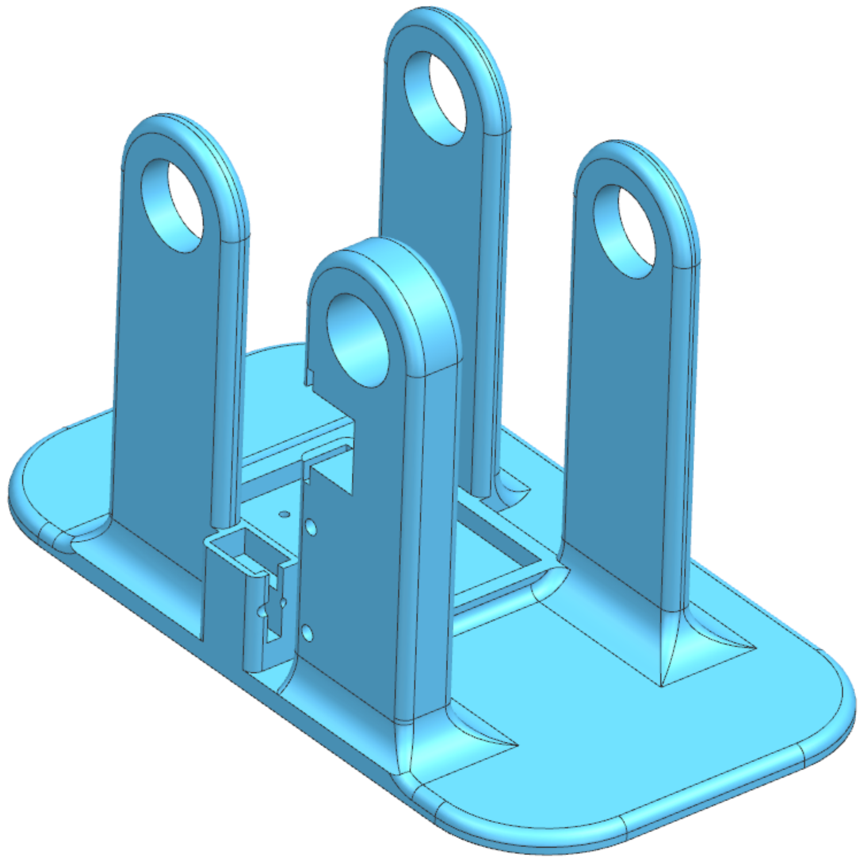
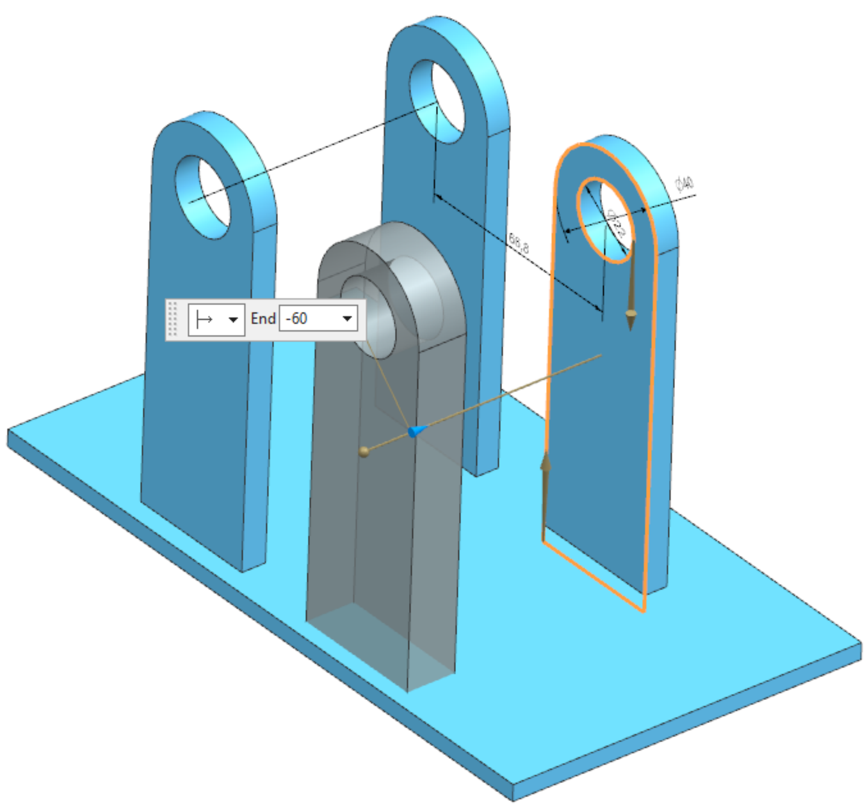
Model Views
Cameras
Model History
Datum Coordinate Sy...
Sketch (1) "SKETCH_0...
Extrude (2)
Sketch (3) "SKETCH_0...
Extrude (4)
Pattern Feature [Circ...
Edge Blend (6)
Extrude (7)
Welcome Page
gear box.prt
large gear.prt
small gear 8 mm.prt
Rcc=9,3
Rac=13,0
Rpc=11,1
p40=1,8
(3,1)
p37=20,0

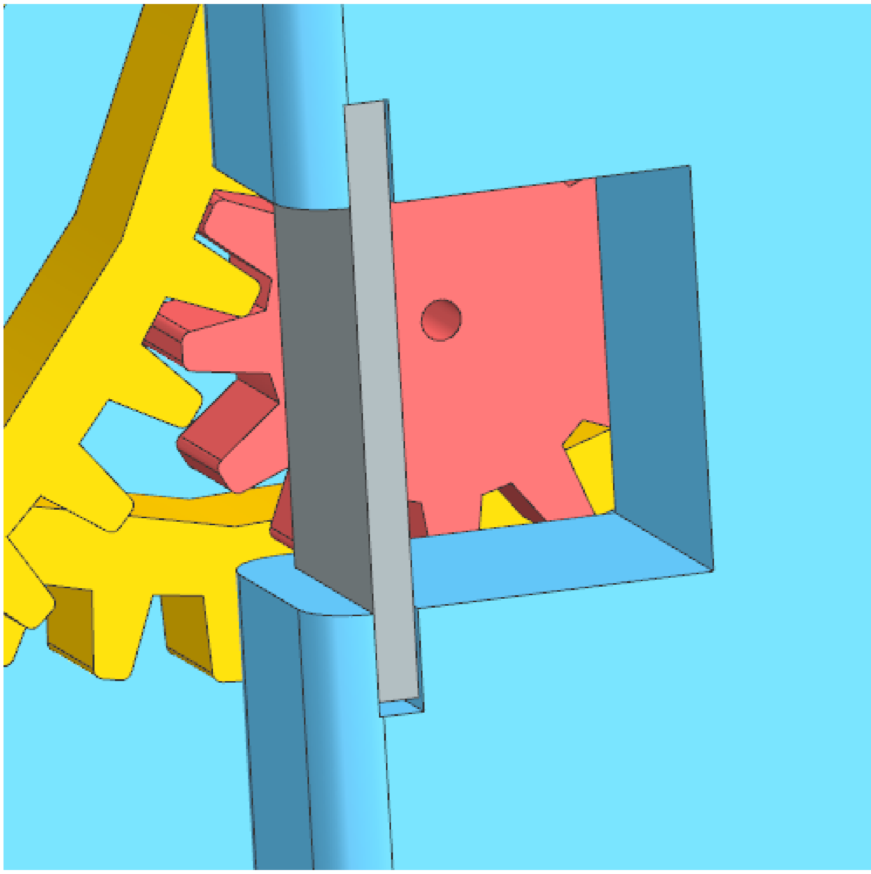
C. Gearbox Design

a. General Design

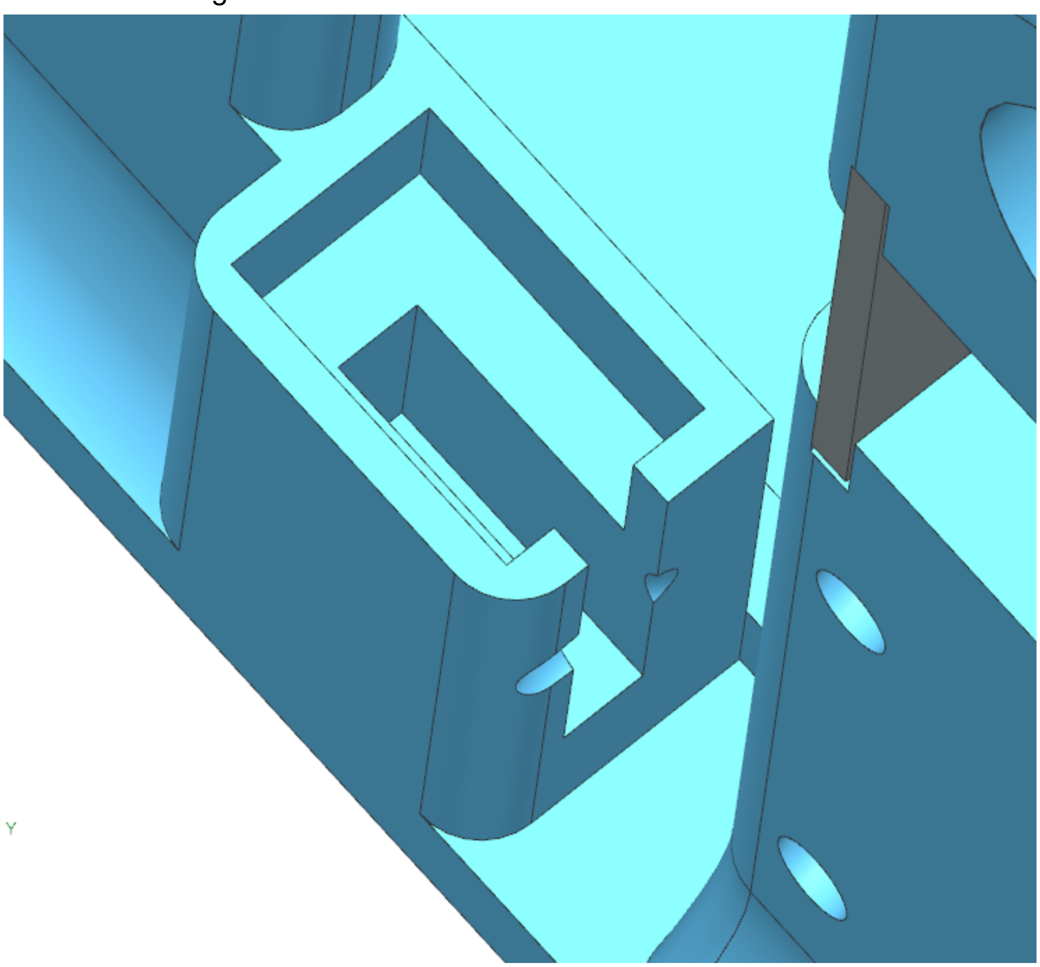




b. Motor mount design



c. Switch seat design



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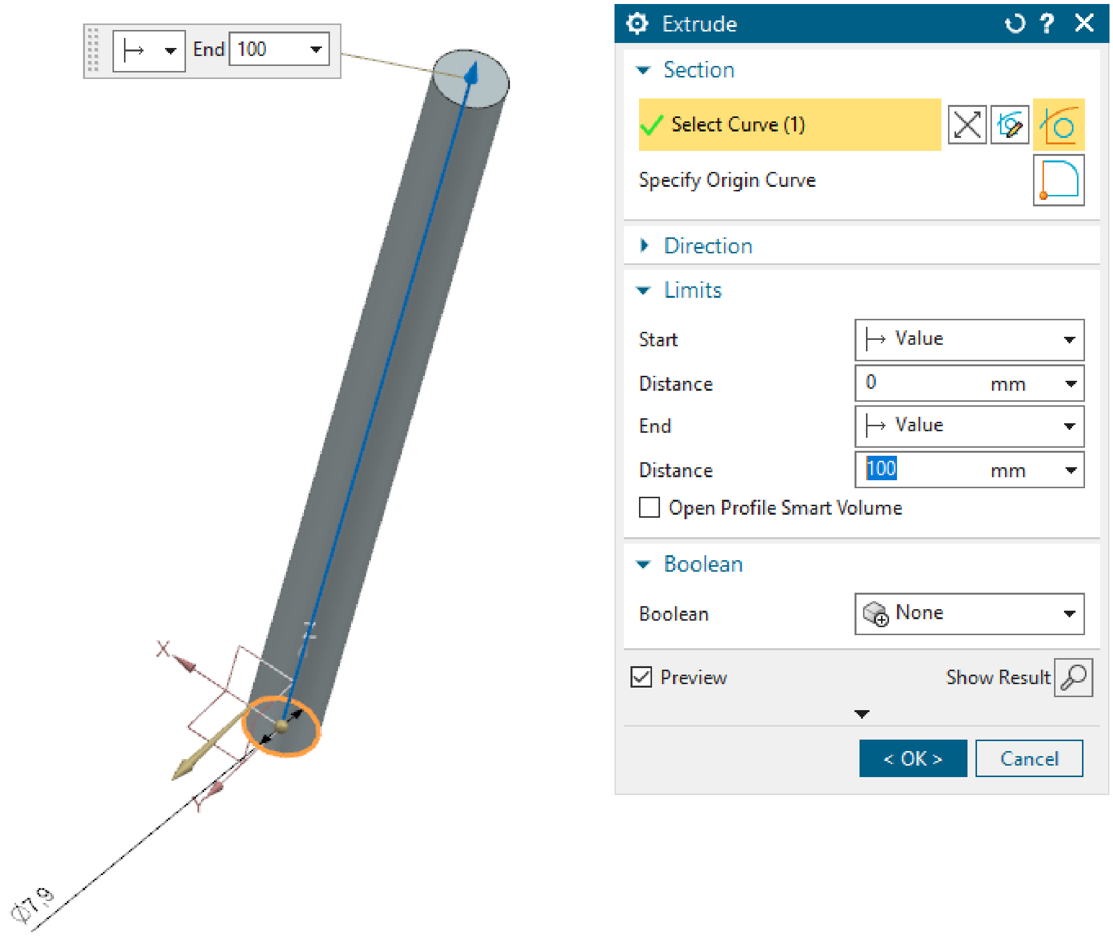
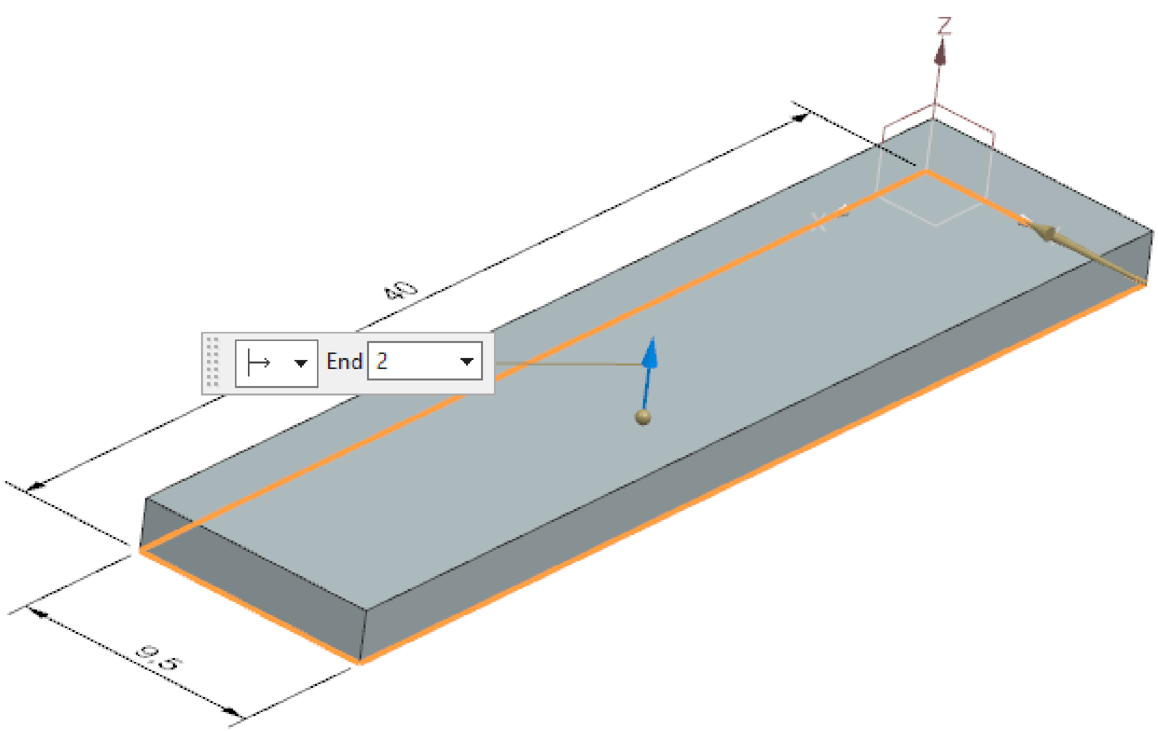
D. Shaft Design



E. Blade Design

a. Blade



b. Centerpiece