Dancing Toy Handoff Demo

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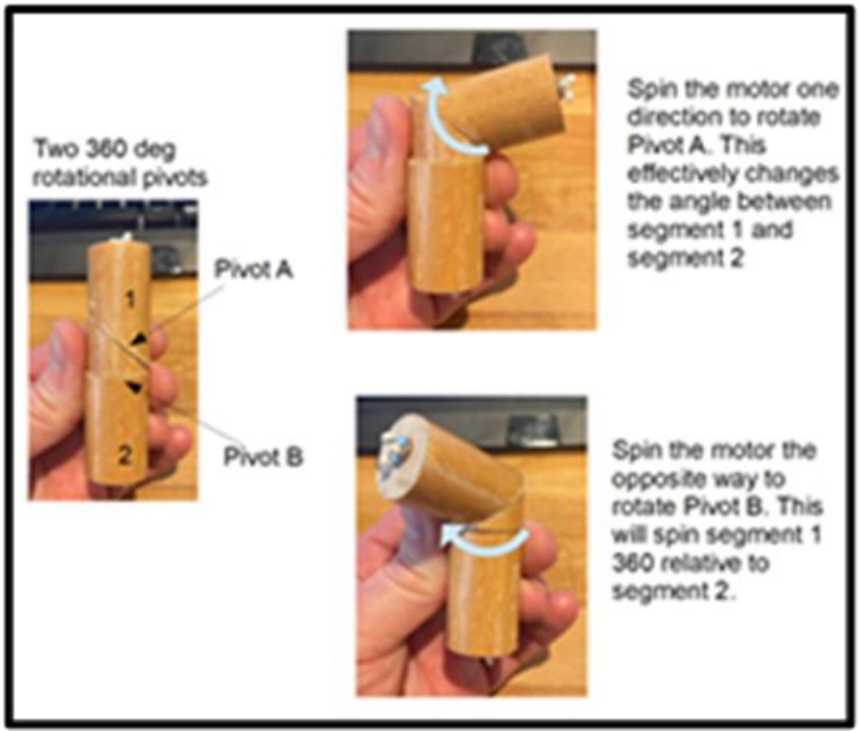
Project Needs

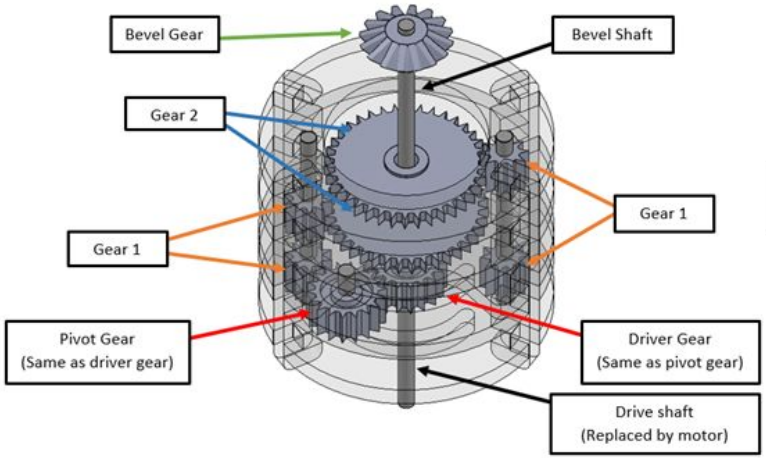


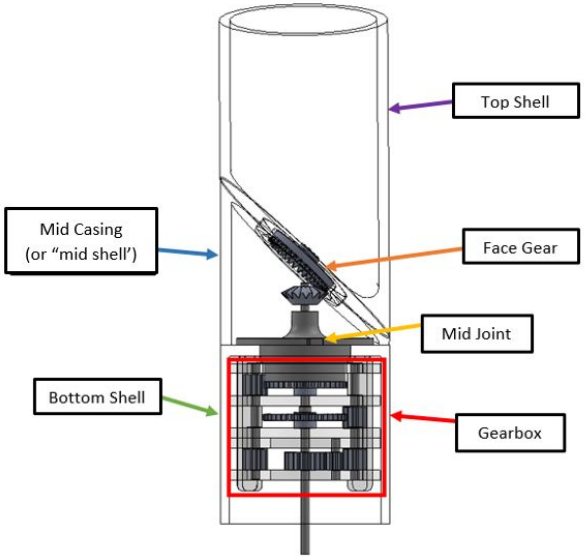
- Assembly functions using a single motor
- Joints rotate 360 degrees continuously
- The axis of the rotation of the joints is offset by an angle
- The assembly structure is strong and durable
- The joint structure is assembled easily
- The assembly functions without generating too much noise

Target Specifications

	Goal or constrain	Gear Box	Flexible Shaft A	Flexible Shaft B	Marginal Value	Ideal Value
Number of motors	Constrain	1	0 (No motor in the prototype)	0	1	1
Degree of rotation (degrees)	Constrain	360	360	360	360	360
Joint angle (degrees)	Goal	90	60	60	45	90
FOS	Goal	N/A	N/A	N/A	1.5	3
Device Diameter (mm)	Goal	40	40	40	40	30
Diameter Height Ratio	Goal	1:3	1:3	1:3	N/A	1:3
Noise Level (dB)	Goal	60	44.2	57	65	30

Last Quarter Progress: Gearbox





ITEM NO.	PART NAME	QTY.
1	BASE PLATE	2
2	SPACER	1
3	MID PLATE	1
4	TOP PLATE	1
5	DRIVER GEAR	2
6	GEAR 1	4
7	GEAR 2	2
8	BEVEL GEAR	1
9	FACE GEAR	1
10	BOX TIE 1	2
11	BOX TIE 2	2
12	SIDE SHAFT	2
13	BEVEL SHAFT	1
14	GEAR PIN	1
15	MID JOINT	1
16	BOTTOM SHELL	1
17	MID CASING	1
18	TOP SHELL	1

Last Quarter Progress: Flexible shaft (A)

- Ratchet structure controlled joints.
- Selected Tygon tube as flexible shaft.
- Bearings added to structure to reduce friction.
- Low Factor of safety and loud noise due to the ratchet design

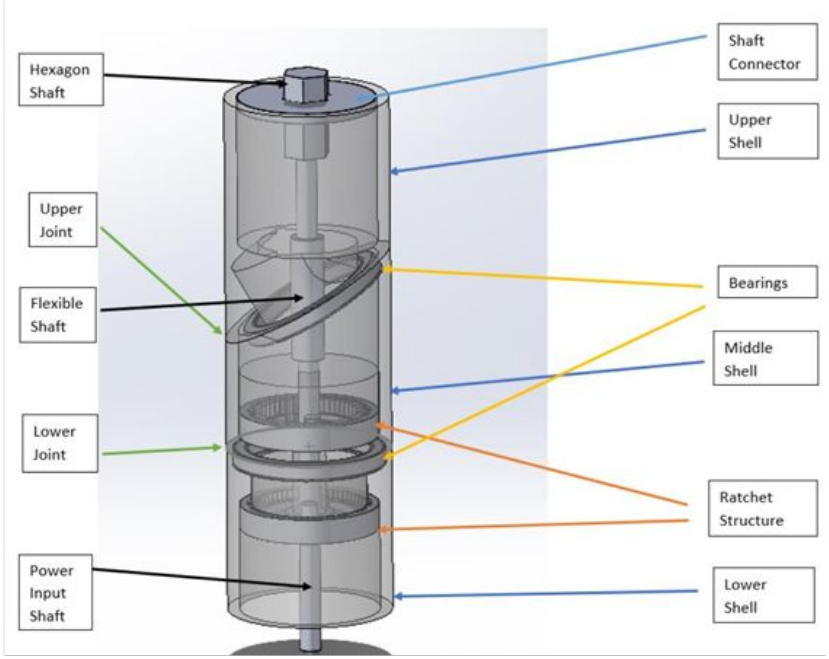
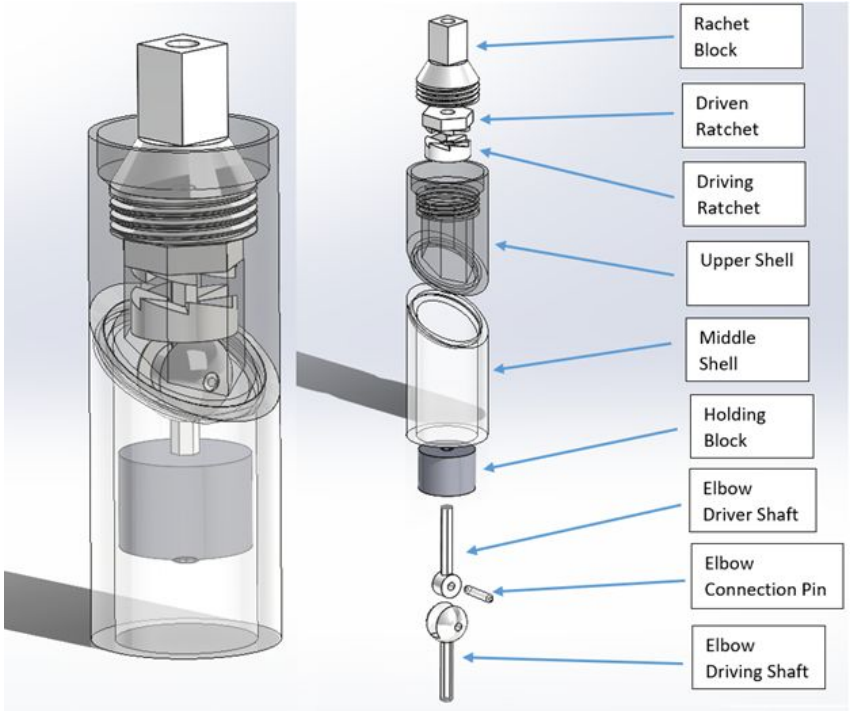


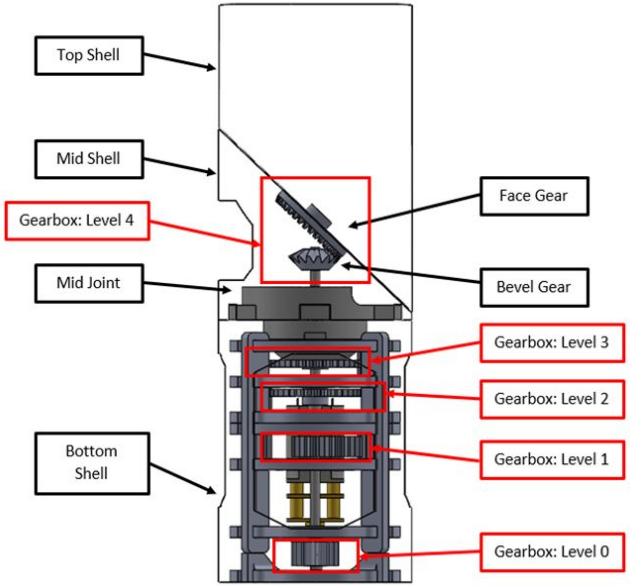
Figure 14: Concept 2 New design

Last Quarter Progress: Flexible shaft (B)

- Simply replace the flexible shaft with an elbow shaft based on the same shell
- Bearing and ratchet installed to function
- Low Factor of safety and loud noise due to the ratchet design

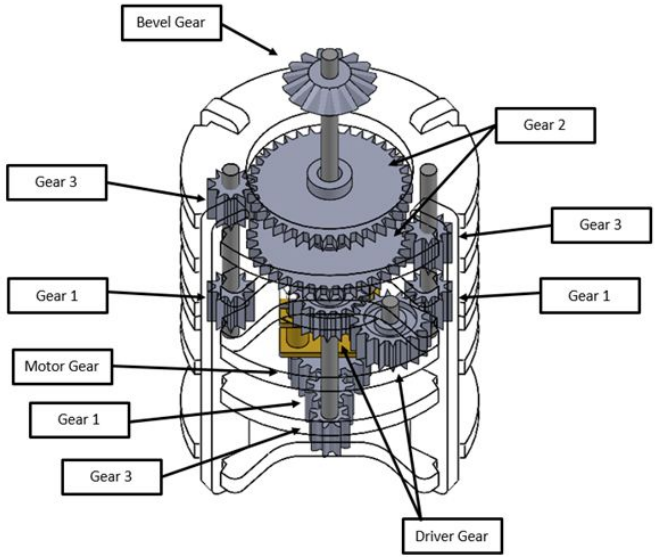


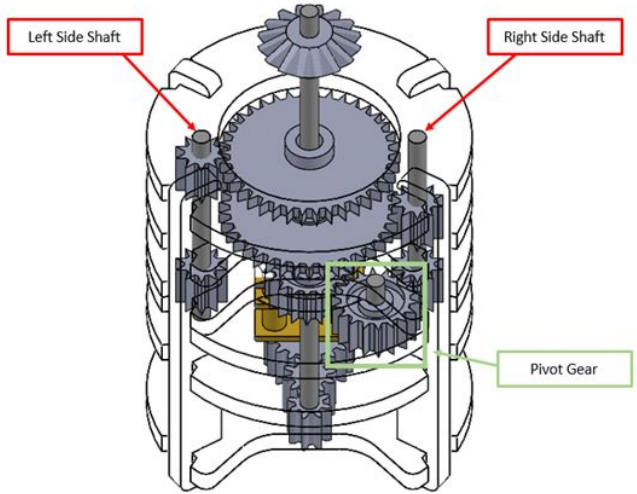
Design Solution: Gearbox



ITEM NO.	PART NAME	QTY.
1	LAYER 0	1
2	LAYER 1	2
3	LAYER 3	1
4	LAYER 4	1
5	LAYER 5	1
6	BOX TIE 1	2
7	BOX TIE 2	2
8	DRIVER GEAR	2
9	GEAR 1	5
10	GEAR 2	2
11	GEAR 3	1
12	BEVEL GEAR	1
13	FACE GEAR	1
14	MOTOR GEAR	1
15	SIDE SHAFT	2
16	Bottom Shaft	1
17	BEVEL SHAFT	1
18	GEAR PIN	1
19	STOPPER	1
20	BOTTOM SHELL	1
21	MID SHELL	1
22	MID JOINT	1
23	TOP SHELL	1
24	MOTOR	1

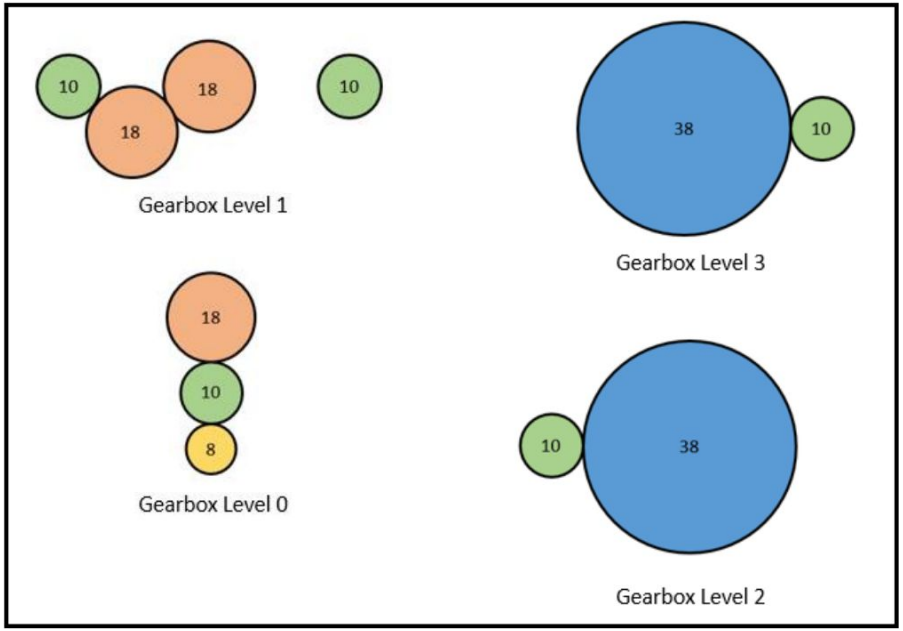
Gearbox Mechanism





Gearbox Levels

Four levels of gears reside in the bottom shell



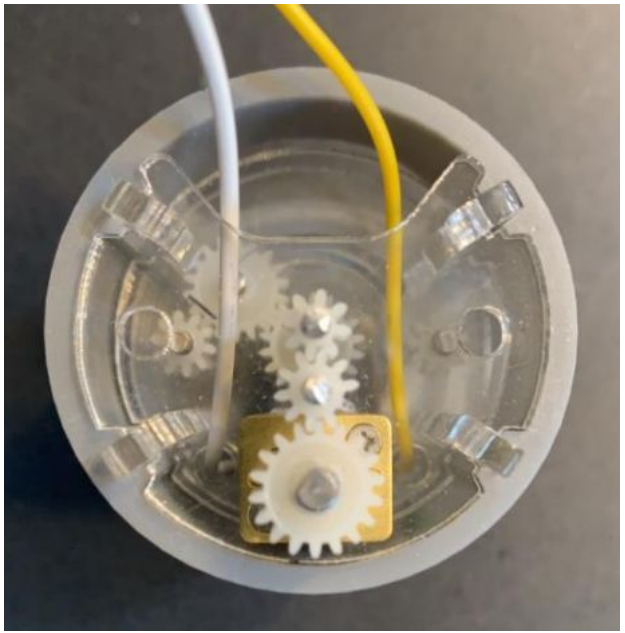
Gearbox Prototype

Fabrication:

- Three shell pieces and mid joint are 3D printed
- Gearbox is made from laser cut acrylic
- Gears and shafts are from a modeling kit purchased online

Improvements from last quarter:

- Stopper was added to constrain gearbox
- Mid Joint and Mid Shell connection was redesigned
- Gearbox layer 0 added
- Joint locks added
- Motor mounting and wiring added
- Shortened top shell, extended bottom shell

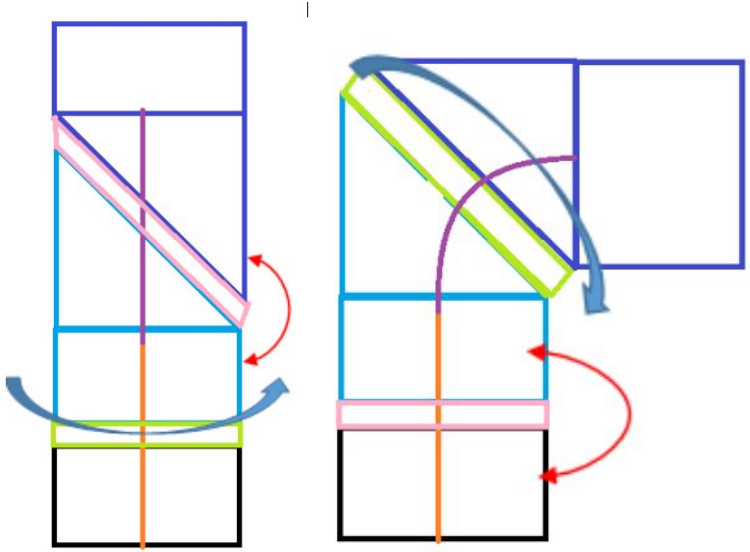


Design Solution: Flexible Shaft (A)

Flexible shaft transfers the power to the upper angled part.

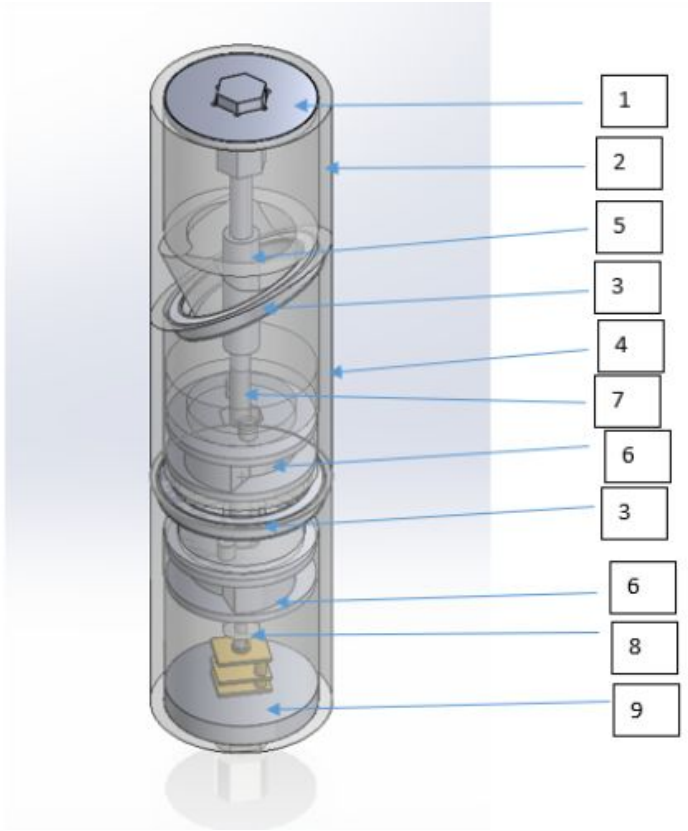
Two ratchet like structures control the movement of each joint.

Bearings are used to reduce friction



Design Solution: Flexible Shaft (A)

Part	Name
1	Hexagon Connection
2	Upper Body Part
3	Bearing
4	Middle Body Part
5	Flexible Shaft
6	One Way Bearing
7	Rigid Shaft
8	Shaft connector
9	Motor mount



- Resin shell and internal structure
- Aluminum internal shaft and hexagon

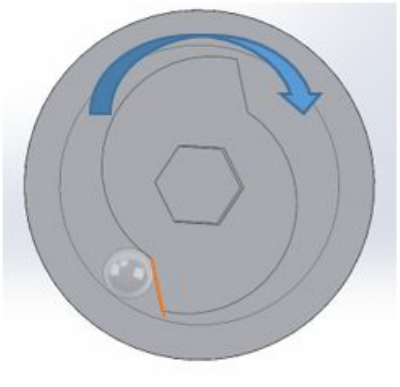
One-Way Bearing Working Mechanism

2 slots and 3 slots internal structure has the best performance

Simple structure

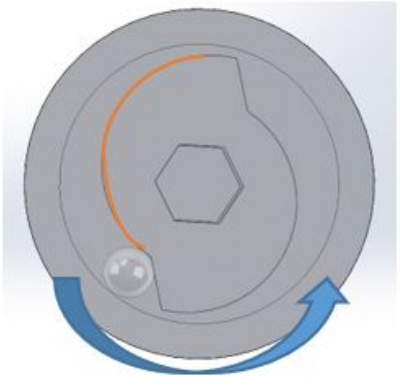
Low noise level

High FOS



Clockwise:

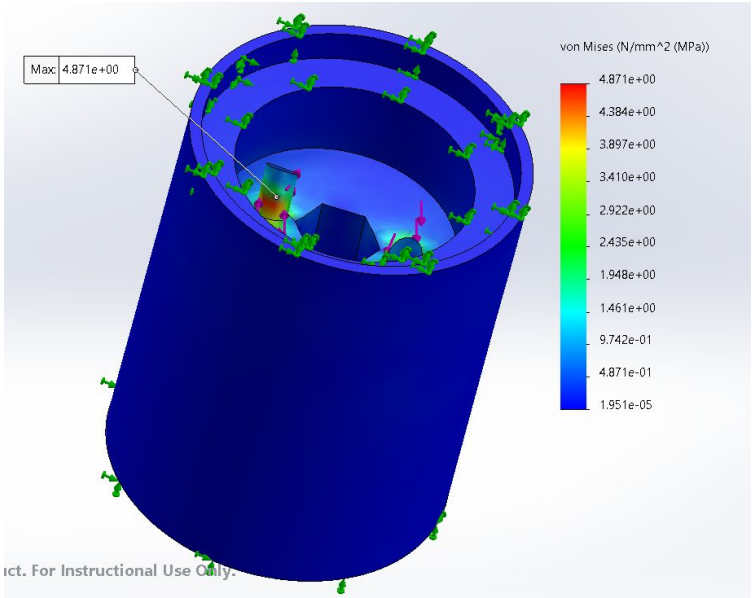
Ball will be pushed by the marked surface to keep moving without locking.

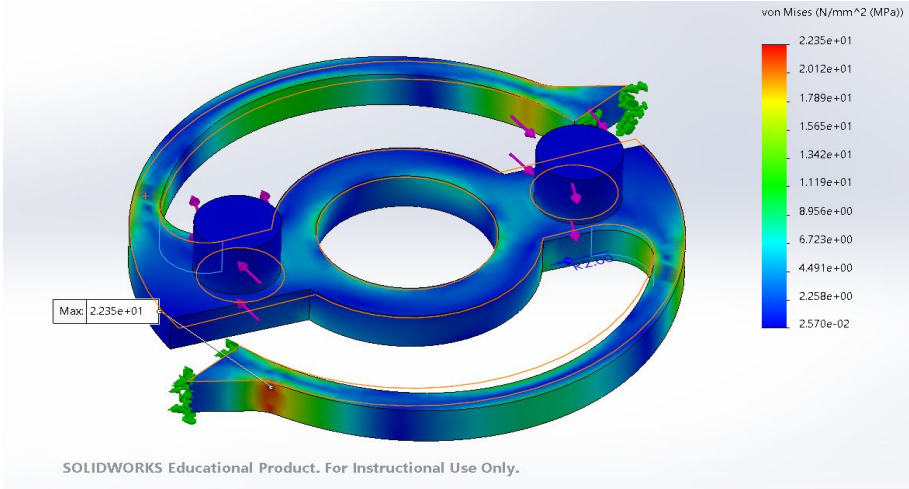


Counterclockwise:

Ball will be squeezed by the decreasing room on the left to lock the internal part with the wall.

FOS Improvement

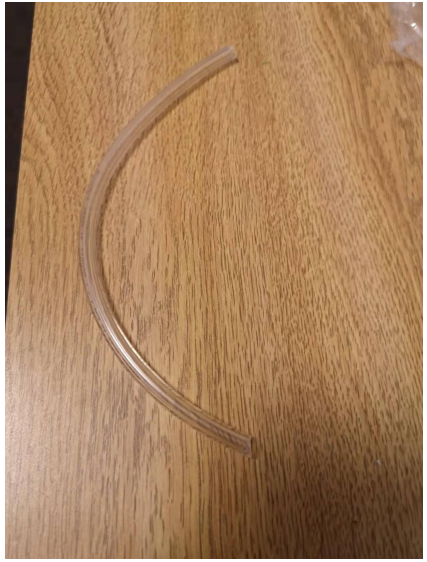


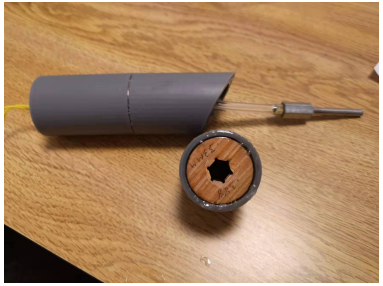


Flexible Shaft (A): Advantages of Tygon tube

- Low Price
- Small bending radius
- Low springback force

Num.	Type (1/4" OD, 1/8" ID)	Bend Radius (inch)	Price (USD Per Ft.)
1	Soft Plastic Tubing for Air and Water (Tygon)	3/8	0.98
2	Continuous-Flex Soft Plastic Tubing for Air and Water (Tygon)	1/2	5.85
3	Low-Temperature Firm Plastic Tubing for Chemicals (Tygon)	1/16	1.54
4	Soft Plastic Tubing for Fuel and Lubricants (Tygon)	1/4	0.98
5	Soft Plastic Tubing for Air and Water (Masterkleer) - too soft	1/4	0.18
6	Crack-Resistant Hard Plastic Tubing for Chemicals (Teflon)	1/2	5.73
7	High-Purity Soft Plastic Tubing (Versilon)	1/2	2.21
8	Super-Soft Rubber Tubing for Air and Water	1	1.17
9	Abrasion-Resistant Firm Rubber Tubing for Air and Water	1 1/2	0.8



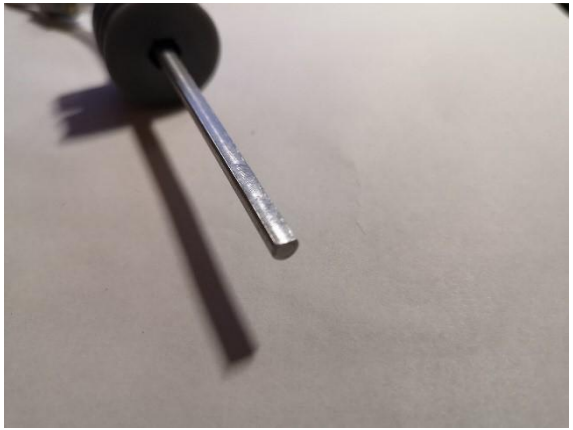


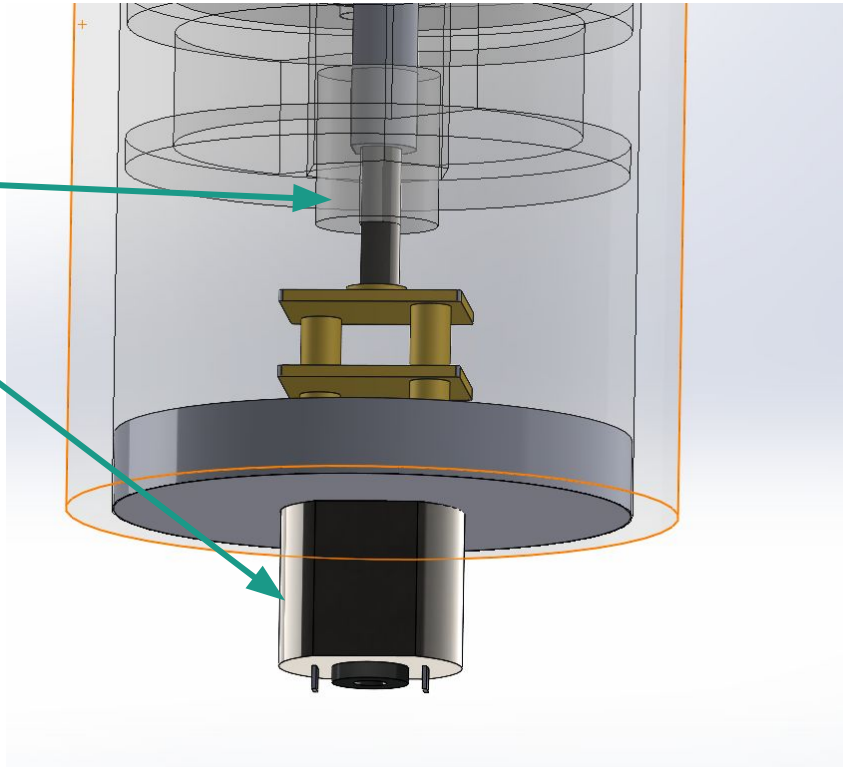
Type	Required Force to bend to 90 degrees (N)
Soft Plastic Tubing for Air and Water (Tygon)	2
Rubber Tubing for Air and Water	10

Flexible Shaft (A): Motor and adaptor

Adaptor connects motor and inner shaft

Motor connects to the base of the joint



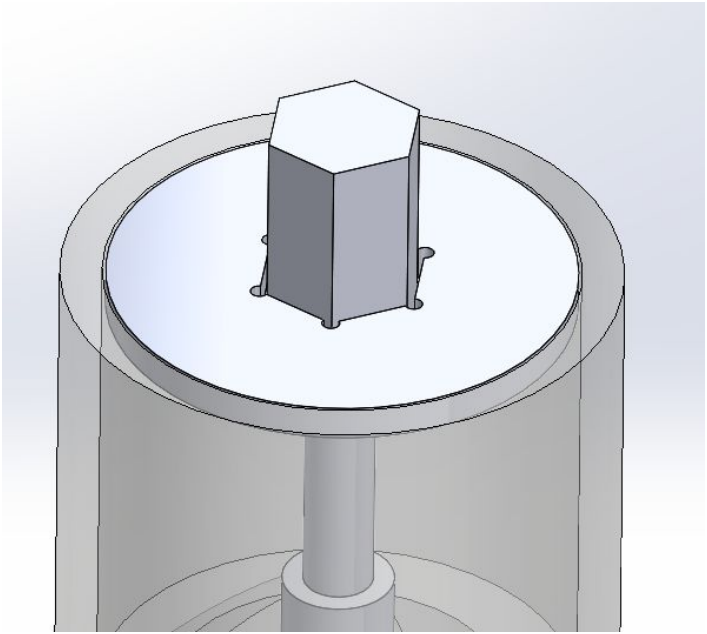


Flexible Shaft (A): Hex Connector

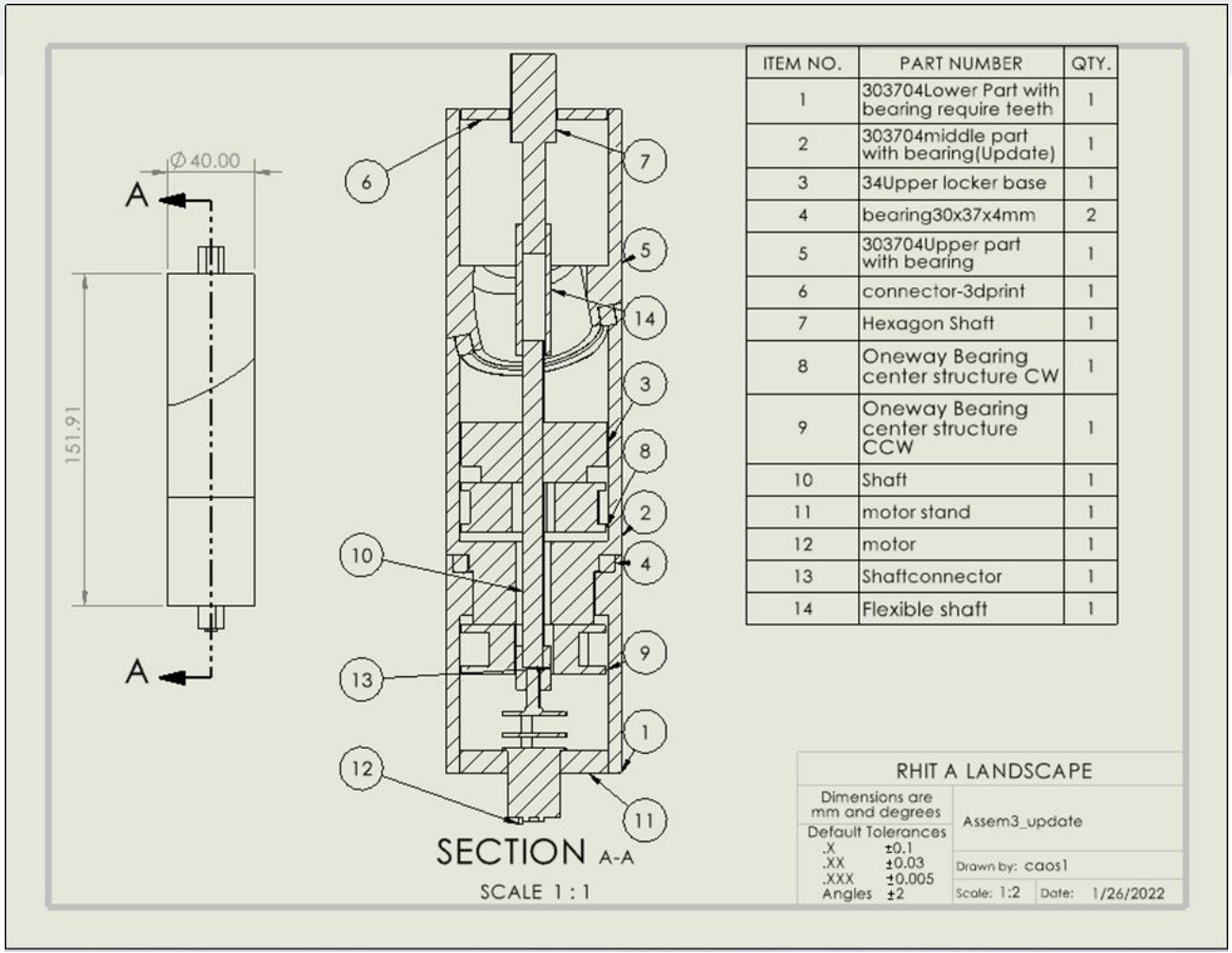
Internal shaft has 2 mm movement when upper part goes to the lowest position.

Hex Connector allow the movement happen.

Hex Connector can transfer the power at any angle.

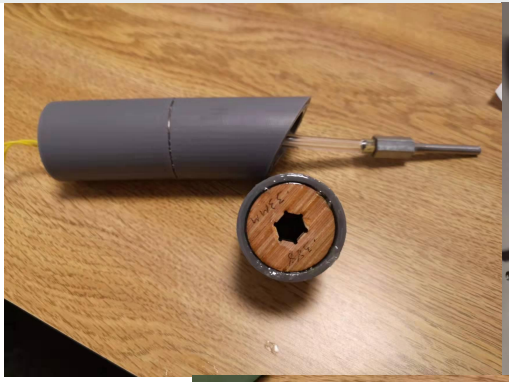


BoM



ITEM NO.	PART NUMBER	QTY.
1	303704Lower Part with bearing require teeth	1
2	303704middle part with bearing(Update)	1
3	34Upper locker base	1
4	bearing30x37x4mm	2
5	303704Upper part with bearing	1
6	connector-3dprint	1
7	Hexagon Shaft	1
8	Oneway Bearing center structure CW	1
9	Oneway Bearing center structure CCW	1
10	Shaft	1
11	motor stand	1
12	motor	1
13	Shaftconnector	1
14	Flexible shaft	1

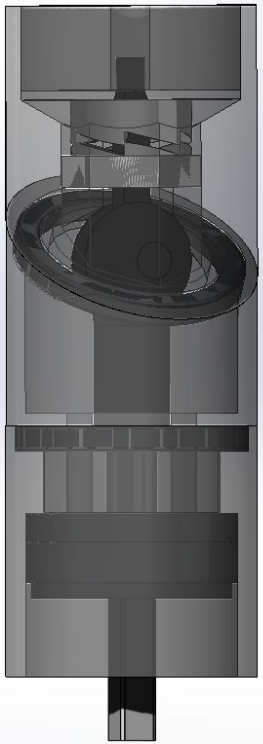
Flexible shaft(A) prototype

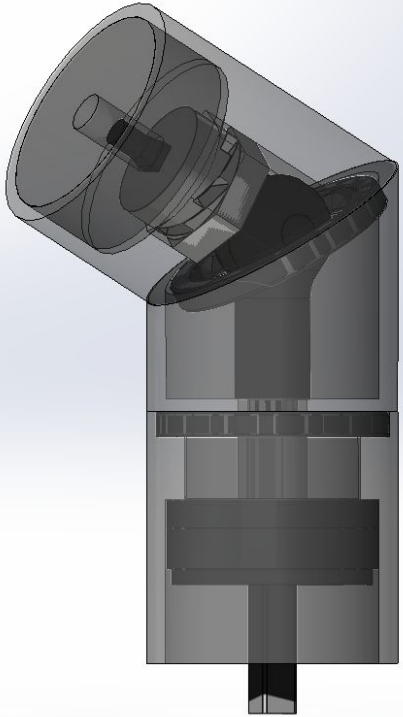


Improvements from last quarter:

- Ratchet structure changed to one-way bearing
- Noise reduced
- Structure FOS increased
- Motor and adaptor added

Design Solution: Flexible Shaft (B)

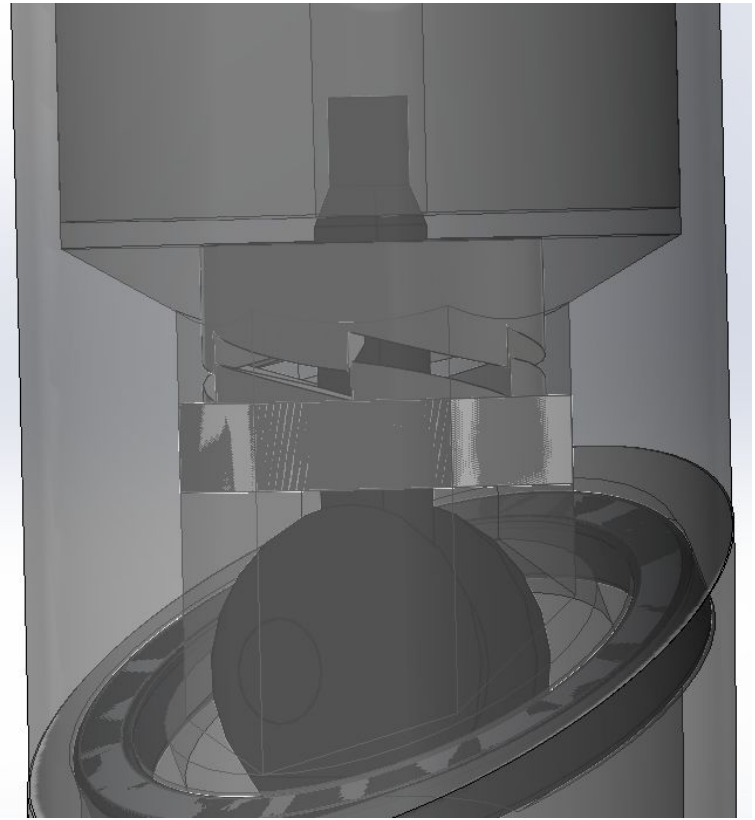




- Preserved the elbow structure from last quarter
- Bearing and new ratchet design applied to assembly
- All parts can be made via plastic
- All parts should be ready for 3D print, some have to be sliced for injection molding.
- Most external structure and connection with motor is inherited from Flexible shaft(A)

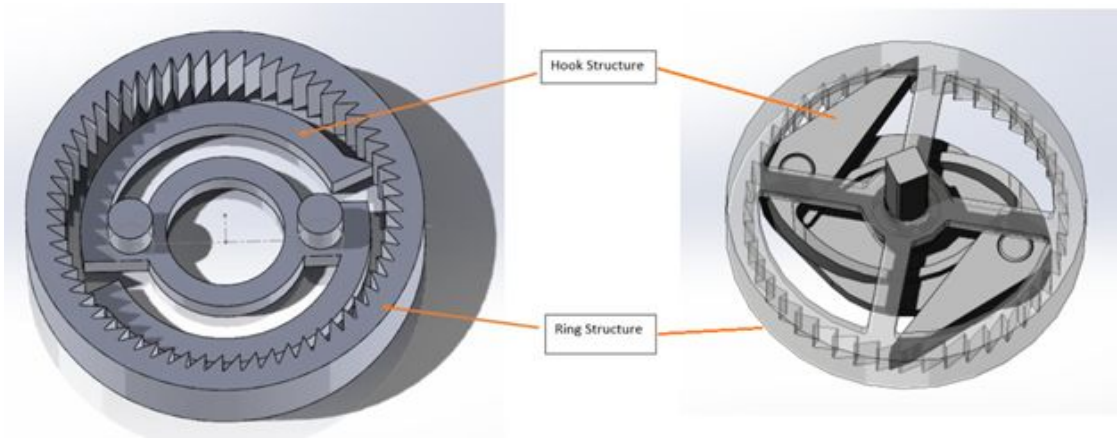
Upper Gear for Flexible Shaft Design (B)

- Two gears with 6 teeth on each side
- Lower gear is hexagonal to drive the outer shell
- Upper gear is round to allow free rotation
- The gear is meant to “kickstart” the movement of the upper stage and does not disrupt the rotation afterwards

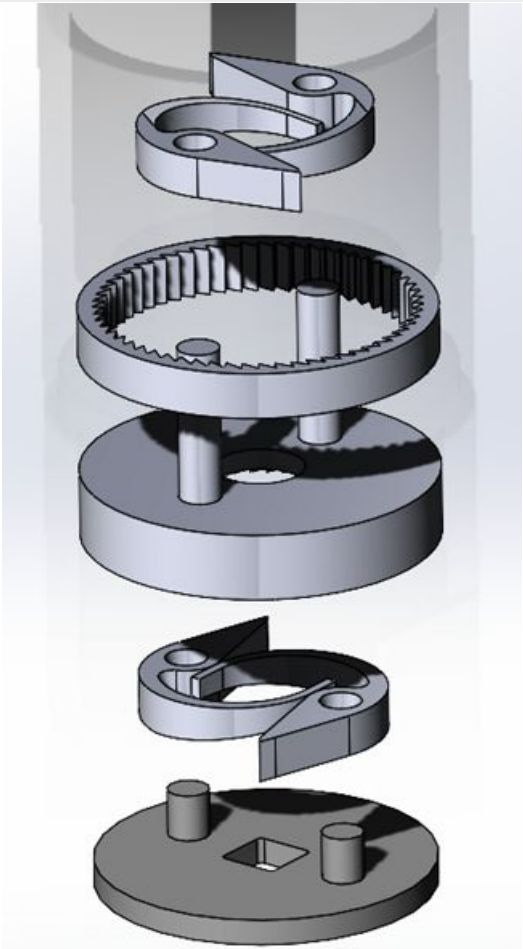


Ratchet for Flexible Shaft Design (B)

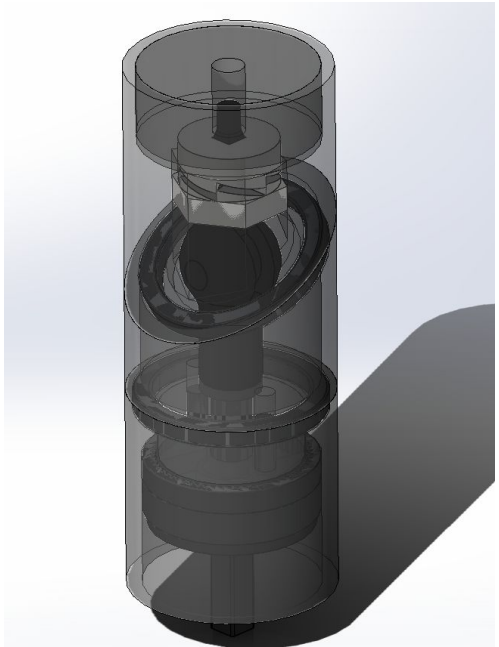
- Elastic arm and hook is now separated to eliminate stress concentration
- Part count increased from 2 to 4 due to separated parts for ratchet

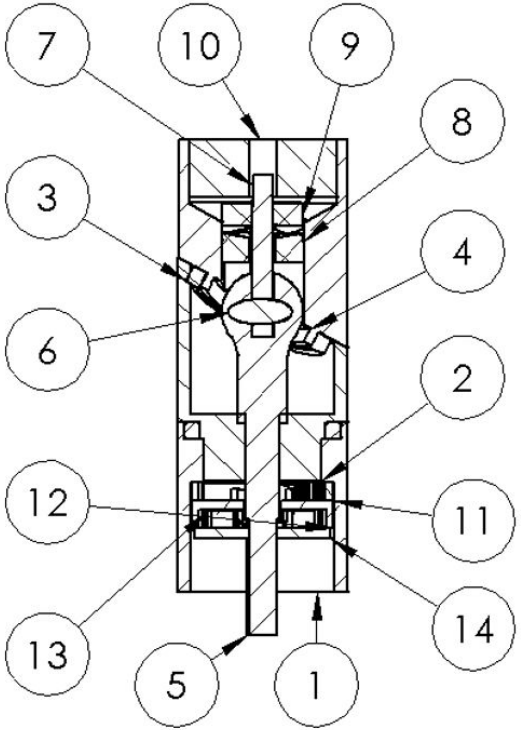


Left: Comparison for old and new ratchet design
Right: Exploded view of the new ratchet application



Bill of Material





SECTION A-A

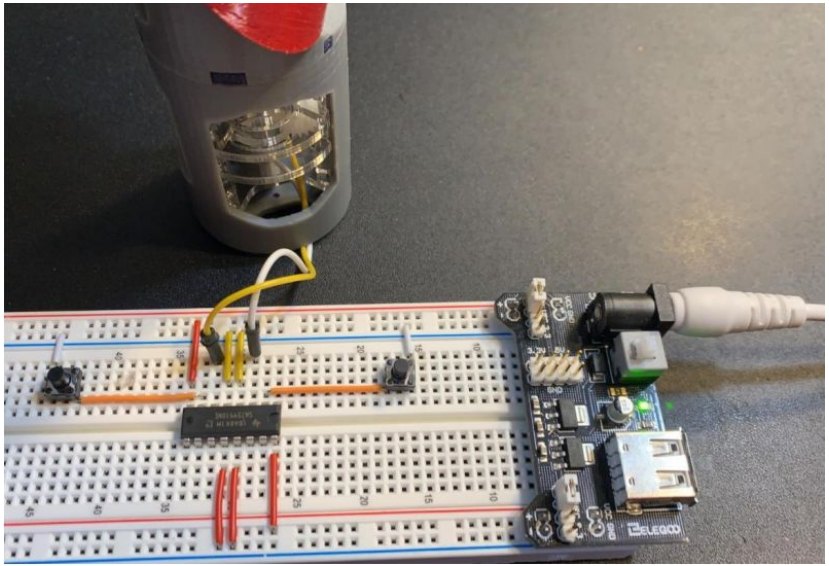
ITEM NO.	PART NUMBER	QTY.
1	303704Lower Part with bearing require teeth	1
2	303704middle part with bearing(Update-2)	1
3	bearing30x37x4mm	2
4	303704Upper part with bearing(Update)	1
5	Elbow Lower Piece	1
6	Elbow Pin	1
7	Elbow Upper Piece	1
8	Ratchet Upper Driver	1
9	Ratchet Upper Driving	1
10	Upper Blocker	1
11	34Tooth ring -CW	1
12	34Tooth ring -CCW	1
13	Ratchet	4

Design Verification: Gearbox

- Design is proven but manufacturing errors cause issues
- Gears slip on their shafts
- Joint 2 will not always move independent of joint 1
- Bevel gear meches poorly with the face gear
- Pivot gear lingers in the neutral position when switching sides
- Mixing and matching parts yields different performance results

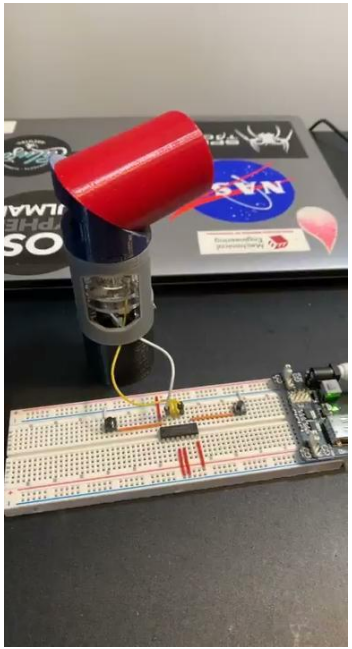
Project Need	Technical Specification	Measured value from prototype testing	Achieved
The device functions using a single bidirectional motor	Number of motors	1	Y
The device rotates 360 degrees at two joints	Degrees of rotation (degrees)	360	Y
When one joint is moving, the other maintains its position	Joints rotate independently (visual inspection)	X	N
The device bends to an angle of at least 45 degrees	Joint angle (degrees)	90	Y
The diameter of the device must be within 30-40 mm	Diameter (mm)	40	Y
The device should have a diameter-height ratio of 1:3	Diameter Height Ratio	1:3	Y
The device should be as quiet as possible	Noise (decibels)	60	N/A

Testing the Gearbox Prototype



Prototype Circuit

Good Test



Poor Test

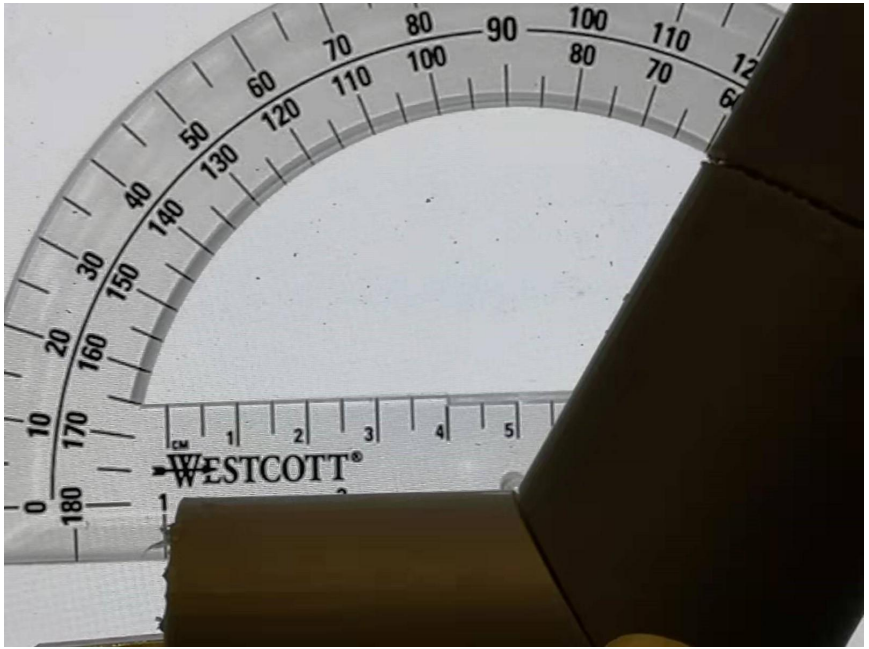
Design Verification: Flexible Shaft (A)

- Prototype works as expected
- Main structure made by SLA printed resin parts
- No slip in one way bearing when testing
- Size ratio is larger than the project goal.
- Low noise level
- Some improvements are needed for reduce assemble difficulty
- Due to the flexibility of Tygon tube, The upper part can be rotated when the motor stopped.

Project Need	Technical Specification	Measured value from prototype testing	Achieved
The device functions using a single bidirectional motor	Number of motors	1	Y
The device rotates 360 degrees at two joints	Degrees of rotation (degrees)	360	Y
When one joint is moving, the other maintains its position	Joints rotate independently (visual inspection)	N/A	Y
The device bends to an angle of at least 45 degrees	Joint angle (degrees)	60	Y
The diameter of the device must be within 30-40 mm	Diameter (mm)	40	Y
The device should have a diameter-height ratio of 1:3	Diameter Height Ratio	1:4	N
The device should be as quiet as possible	Noise (decibels)	51(CW) 54(CCW)	N/A

Flexible Shaft (A) Size

Flexible Shaft (A) Bending Angle



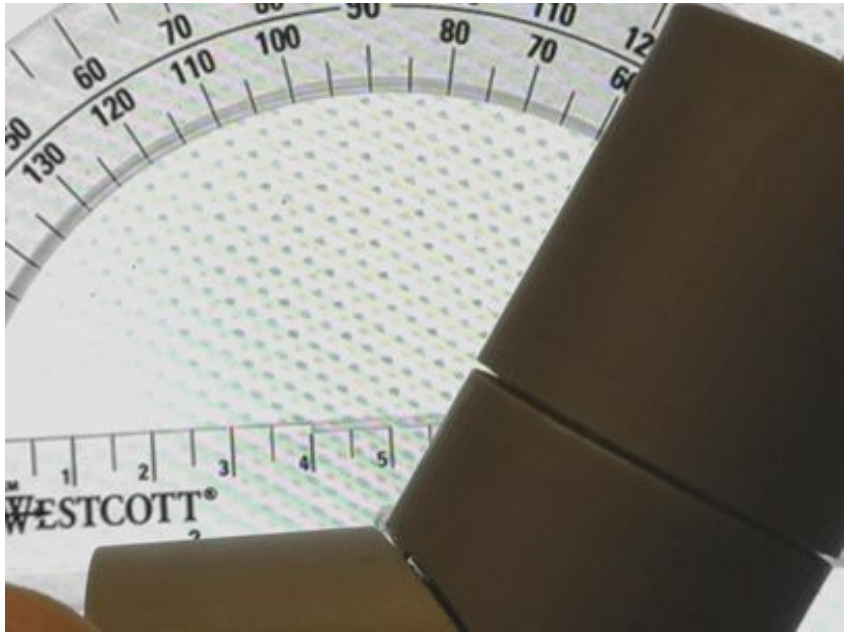
Testing the Flexible Shaft (A)

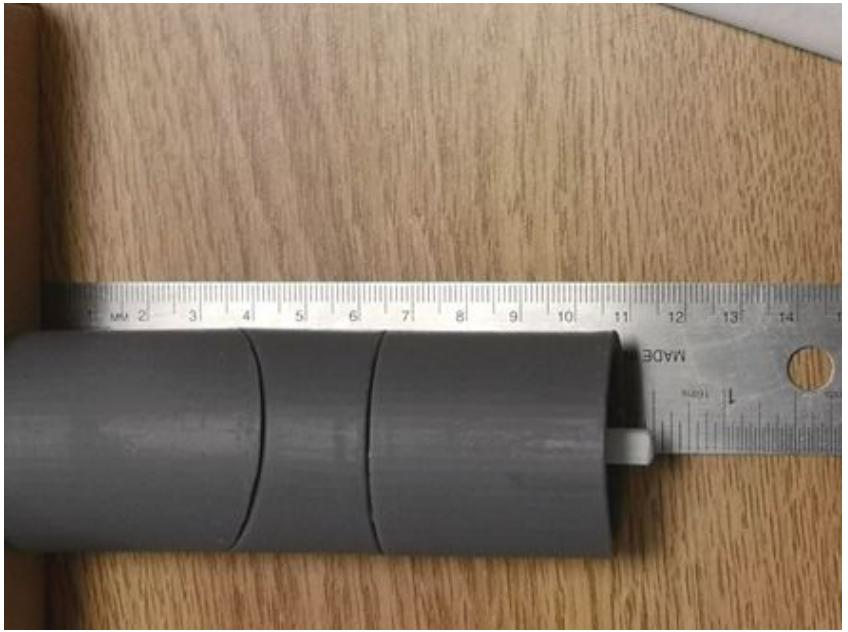
Design Verification: Flexible Shaft (B)

- Prototype is working, but with an extra “spinning up” period for the ratchet to lock on.
- Noise level measured is majorly environmental noise and motor noise.
- Slightly larger diameter-to-height ratio than requirement
- Highly variable joint angle from 0 degrees to 90 degrees

Project Need	Technical Specification	Measured value	Achieved
The device functions using a single bidirectional motor	Number of motors	1	Y
The device rotates 360 degrees at two joints	Degrees of rotation (degrees)	360	Y
When one joint is moving, the other maintains its position	Joints rotate independently (visual inspection)	N/A	Y
The device bends to an angle of at least 45 degrees	Joint angle (degrees)	60	Y
The diameter of the device must be within 30-40 mm	Diameter (mm)	40	Y
The device should have a diameter-height ratio of 1:3	Diameter Height Ratio	1:3.16	N
The device should be as quiet as possible	Noise (decibels)	57	N/A

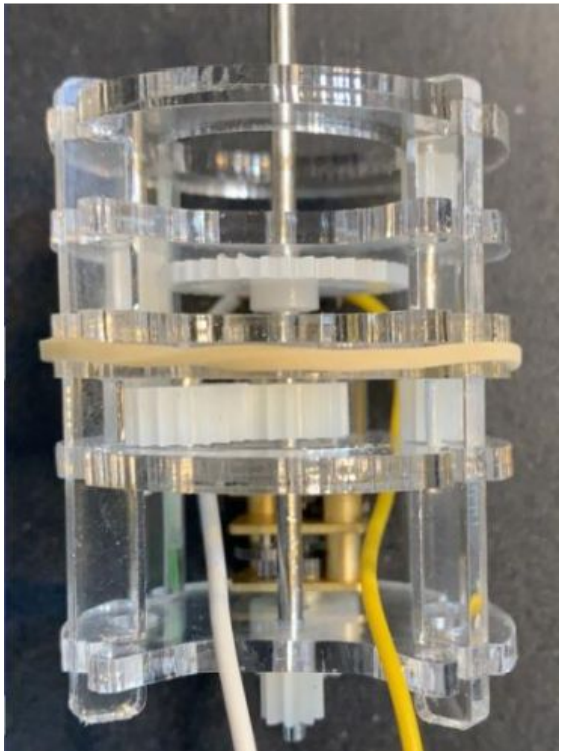
Flexible shaft (B) bend angle and length





Final Comments: Gearbox Design

- Design works, prototype does not
- Increase motor speed or adjust gear ratios for more speed
- Fabricate custom face gear and bevel gear
- Lubricate mechanism
- Replace locking mechanism with snap fits



Final Comments: Flexible Shaft (A)

The upper part cannot follow the motor movement perfectly:

- Cause by the flexibility of Tygon tube.
- Flexible shaft can be changed to a rigid shaft or a stiffer shaft which have high torsional resistance

Size ratio did not match the requirement:

- Internal ratchet connector can be removed to reduce the size requirement.
- Reduce the one way bearing height in the future.

Better part to part connection need to be added in the future.

- Major connection in the prototype used glue and friction between parts
- Snap design can be added in the future design.

Final Comments: Flexible Shaft (B)

- The problem of starting the rotation of the upper segment while it is upright still persist, and the current gear sets isn't reliable enough.
  - Replace the current gear pair with additional ratchet set
- The new ratchet currently requires an extra "spin up" distance of about 6 degrees to 60 degrees
  - Strengthen the elastic part in the ratchet will solve this, but with penalty of larger noise and difficulty to assemble

Questions