BME Design-Fall 2023 - MAXWELL NASLUND
Complete Notebook

PDF Version generated by

Amber Schneider

on

Dec 14, 2023 @08:38 PM CST

Table of Contents

Team contact Information

Kendra Besser - Sep 10, 2023, 12:58 PM CDT

Last Name	First Name	Role	E-mail	Phone	Office Room/Building
Trevathan	James	Advisor	jtrevathan@wisc.edu	n/a	
Tang	Jiayi	Client	jtang263@wisc.edu	n/a	
Naslund	Maxwell	Leader	mjnaslund@wisc.edu	952-484-9086	
Besser	Kendra	Communicator	kbesser@wisc.edu	651-252-7872	
Uy	Caspar	BSAC	cuy@wisc.edu	414-861-2444	
Schneider	Amber	BWIG	amschneide23@wisc.edu	612-581-0092	
Flogel	Jamie	BPAG	Jflogel@wisc.edu	608-354-4265	

Project description

Jamie Flogel - Oct 10, 2023, 8:05 PM CDT

Course Number: BME 400

Project Name: MRI Compatible Motion Platform

Short Name:

MRI Platform

Project description/problem statement:

Integration of a nonmagnetic ultrasonic motor into a larger, minimally-metallic mechanical assembly in which the motor moves a platform inside the high magnetic field strength environment of an MRI scanner. Development of software, firmware, and possibly electronic circuitry to allow for control of the platform.

About the client:

Mr. Jiayi Tang is a PhD student at UW-Madison in the Department of Medical Physics as well as a research assistant in the Quantitative Imaging Methods Lab. His studies are focused on the implementation, evaluation, and improvement of motion-robust qMRI sequences on liver phantoms.

2023/09/12-1st Client Meeting

Kendra Besser - Sep 12, 2023, 1:45 PM CDT

Title: First Client Meeting

Date: 9/12/2023

Content by: Jamie

Present: Entire Team

Goals:

-Learn more about the client

-Learn more about goals for the project

-Discuss next steps

Content:

Questions:

- Budget?
    - $1000 but could extend
- How often do you want us to check in?
    - When needed, he has relatively open schedule
- Other than respiratory, what motion patterns are we trying to mimic?
    - At least a sliding platform in and out, then add respiratory (he has sin wave generation of typical respiratory), maybe more motion later
- Can we meet to get the supplies?
    - Kendra will email and coordinate
- Should we start on the basic MR safety screening? How do we get our prototype cleared by the MR safety committee for testing?
    - He will get back to us
- Dimensions of prototype? Size of a human or small scale?
    - Soccer ball (small scale)
- Aesthetics?
- Any resources (contacts, articles, ect)?
- Other expectations of us for the semester?
- Is quantitative MRI a new concept?

Jiayi Tang
-2nd year PhD student
-Lab works on motion-robust quantitative MRI
-MRI tends to be qualitative but can be used as a measuring tool (Quantitative)
-Can measure fat and iron and elasticity of liver
-Normally would need to biopsy but that is invasive
-Patients need to hold their breath which is very difficult because methods are not motion-robust
  -Need to repeat scans and cant use technique on all patient populations (children & elderly)
-Want something that moves back and forth depending on timeline
-Make a device that can move and is MR compatible (0 magnetic metals (can use a little aluminum or brass but no steel)
- 3T in MRI Machine
-Known fat concentration and then assess how good our motion robust sequences are
-Not used for patient device would be used for testing/simulating patients organs

-End goal allows patients to breathe freely during the scan
-Start off with one motion and make more complex
-Client is very flexible on the direction of the project with core focus of MR compatible motion platform
-Possible directions include PID loop, waveforms corresponding to respiratory movements, computer platform user interface, sliding and compressive motion of organs (x,y stage)
-presence of magnetic motor reduces quality and further distance better quality results (motor at one end moving platform at other end)
-Only move very small range (inches)
-Soccer ball sized field of imaging
-Have ultrasonic motor available for us to use (likely most expensive component involved)
-Budget of ~1000 but there is grant money available if there are reasons for more
-Also have plastic sliding rails available to use
-Materials available from client near east end of campus, could facilitate drop off or demonstration
-Can meet this Friday at 1:30 generally is free Fridays 12-2
-Electronics need to be outside the room as much as possible
-Will get back to us on availability for testing and where we are allowed to be for testing (may need safety screening)
-There is potential to be in the room with MR equipment but would need to book a time with the client for supervision
-There is a scanner reservation system (it’s currently busy season due to a conference in November)
-Client is flexible about when we check in and we can meet whenever is needed

Understanding before meeting:

- Motion platform that mimics human movement in The order to test qMRI machines
- The platform goes into the MRI by itself (no tissue or patient on it)

Conclusions/action items:

The motion platform will mimic the human movement in order to test the quality of qMRI machines. It will hold samples of tissue with different known fat composites and determine if the qMRI can counter the human motion and define the amount of fat.

2023/09/22-2nd Client Meeting

Kendra Besser - Sep 22, 2023, 2:09 PM CDT

Title: Second Client Meeting

Date: 9/22/2023

Content by: Kendra

Present: Kendra, Jamie, Max, Amber

Goals:

-Learn more about the existing materials

-Learn more about goals for the project

-Discuss competitive designs

Content:

- The client demoed the motor and set up code
- the client showed us the MRI room and where the device can be situated with a hole in the wall to connect to the MRI machine
    - we can access the computer room but the MRI room needs special requirements

given materials consist of:

- ultrasonic motor
- breadboard and microcontroller
- extra long wire to connect motor and breadboard
- plastic rails
- glass beads bearings

Notes on competitive designs:

- the other designs tend to be over 5k to purchase
- our design should be accessible to the public (open sourcing the prototype)
- other designs have very specific components
    - specific wall outlets that can only work with the one product
    - specific phantom/sample holders - will not support creatively built phantoms

Conclusions/action items:

After meeting with the client, we have a better understanding of where we will be testing of prototype and how it will be set up. We will work with the existing materials to develop a unique design. Our design will be different from competitive designs because it will be more affordable and accessible to the public. In addition our design will be capable of supporting different sizes and types of phantoms.

2023/10/30-3rd Client Meeting

Kendra Besser - Oct 30, 2023, 8:28 AM CDT

Title: Third Client Meeting

Date: 10/30/2023

Content by: Kendra

Present: Kendra, Jamie, Max, Amber, Caspar

Goals:

-ask about linear slides materials

-update client on progress

Content:

- we will need a longer linear slide to allow for max motion
- we found the original one but we can not order from Ingus because we don't have an account
- we are thinking we need a length about 300mm
- we are supporting the platform and the rack within the rack and pinion
- Ingus is made to order (takes 6 to 8 weeks to get)
- also the tolerance are very poor
- he had ordered a second rail that was very sticky and too high of friction
- $106 for the original rail
- do not use aluminum because it would be so strong of current it would be difficult to move and it may affect certain types of imagining
- we should attempt lubrication of plastic slides before using metal slides
- we can try to wear down the sticky slide
- Jiayi will contact someone at igus to get 2 380mm rails
- jiayi has rasberypies to work in if the microcontroller does not work
- the third pin is an index pin could use that instead of a homing switch
- with the rack and pinion we will have to make sure the platform stays within the slider limits (so we need a homing switch)
- jiayi used screen (terminal) to run code

Conclusions/action items:

After the client meeting, we have a better understanding of what materials we should be using for the sliders. We will avoid using metals and instead edit our prototype to fit the requirement of plastic use only. The client is up to date on our design and fabrication of both the mechanics and the software.

2023/09/08 Day 1 Activities

Amber Schneider - Sep 08, 2023, 1:25 PM CDT

Title: Day 1 Activities

Date: 9/8/2023

Content by: Amber Schneider

Present: Max, Caspar

Goals: outline and complete day 1 activities

Content:

Team Roles:

1. Kendra Besser - Communicator
    1. Contact your Client (email a link to your website) - use professional etiquette.
2. Jamie Flogel - BPAG
3. Maxwell Naslund - Team Leader
    1. Setup your Notebook (both continuing and and new projects - need a NEW notebook)
        1. Create your team notebook – Team Leader ONLY
4. Amber Schneider - BWIG
    1. Assign your team roles to your teammates on your webpage – BWIG ONLY
    2. Upload your team photo
5. Caspar Uy - BSAC
    1. Sign up to be a Mentor (BME 300 and 400 BSAC members only or any other Junior+ interested in mentoring).

Weekly Advisor Meeting Time: Fridays, 1:30-2:00 pm

Conclusions/action items:

1. Review the course schedule and resource page found on the top navbar of the webpage "course" when you are logged in
2. Start researching your project
3. TEAM LEADER prepare the First Progress Report (**use proper file naming etiquette i.e. catch_phrase-progress_report-date**),
   BWIG – upload it to the webpage
   COMMUNICATOR - email the link to the progress report to your advisor and client, cc your team (due by 5 pm next Thursday)

2023/09/15 Advising Meeting 2

Amber Schneider - Sep 15, 2023, 2:02 PM CDT

Title: Advising Meeting 2

Date: 9/15/2023

Content by: Amber Schneider

Present: Max, Caspar, Jamie, Kendra, Dr. Trevathan

Goals: outline progress from the past week, define expectations for the next week

Content:

- Discussed client meeting
- Described understanding of the project

Questions to ask the client

- what are the goals for the use of the device
- Quantitative specs

Semester Outlook

- Weekly lab archives check or "midterm" lab archive grades
  - decide as a team by next week
- Grading
  - if you're doing the minimum --> based off the rubric
  - in a useful way, treat as real world project --> lenient on grade rubric
    - **Preferred**
- What's Next
  - PDS due Friday
    - get better idea of specifications during second client meeting
    - material limitations in MRI room
      - get idea of what the limitations are & how to operate within them

2nd Semester

- use testing to learn from
- improve design of prototype

Conclusions/action items:

Discussed the progress the team has made the past week. Action items include having a second meeting with the client, continue research on MRI and design constraints, and drafting the PDS.

2023/09/22 Advising Meeting 3

Jamie Flogel - Sep 22, 2023, 1:52 PM CDT

Title: Meeting notes for third advisor meeting

Date: 9/22/2023

Content by: Jamie

Present: Amber, Kendra, Max

Goals:

-Check in on progress

Content:

-Discussed the materials provided to the team by the client

-Discussed potential use of an ardiuno to run motor software

-Discussed updates for PDS

-Discussed focus on cost and adaptability features of our design

-Biggest limitation will likely be size and weight supported by our phantom

-Goal for next week will be to better define our options going forward

-Make sure to address speed options

-Make sure we are addressing that the specifications meet the goals of the client

-Using quantitative metrics in the design matrix will be useful

Conclusions/action items:

We will continue to work on the PDS and before turning it in tonight. We will begin to brainstorm ideas for the design matrix. We should continue to do relavant research for the project.

2023/09/29 Advising Meeting 3

Amber Schneider - Sep 29, 2023, 1:56 PM CDT

Title: Advising Meeting 3

Date: 9/29/2023

Content by: Amber Schneider

Present: Max, Caspar, Jamie, Kendra, Dr. Trevathan

Goals: discuss past weeks work, understand expectations for upcoming week

Content:

Discussion Design Matrix

- Ideas focused on how to translate rotational motion into linear motion
- Idea 1: lead screw
    - Previously discussed with the client
    - limited by resolution of 3D printer
- Idea 2: scotch yoke
    - reciprocating motion
- Idea 3: rack & pinion
    - efficient, controlled motion
- Design Matrix criteria: efficiency, accuracy, ease of fabrication, cost, adjustability, safety, durability
    - pros/cons for each design
    - "winner" was rack & pinion (idea 3)
- **Advisor Feedback**
    - try to gain better understanding of what is available to buy vs what we need to fabricate
    - Inputs: mass to move, waveform to replicate (position vs. time)
        - how much acceleration?
        - what does the force need to be?
        - translate torque of motor to force needed to apply
        - determine gear ratio
    - Move mass (& safety factor), accommodate different waveforms
    - Transfer torque to linear motion with X efficiency, include gear ratio

Discussion of Presentation

- Be as quantitative as possible with specifications
    - not a lot of unknowns
    - **calculations**
    - design choices (choice of mechanism), plans for testing
- use clients reasoning for specifications (for now)
    - client might not know exactly what he's looking for
    - identify what will accomplish the purpose of the design
- Send slides by Tuesday/ Wednesday to get quick feedback

Discussion of Fabrication

- Nylon, plastic gears for purchase online
- Can try to purchase some common things to reduce error, speed up fabrication process
- expect to have issues with 3D printing

- may be over crowded this semester

Conclusions/action items:

We met with our advisor to discuss our work on the design matrix. Discussed expectations for upcoming presentation. Action items include:

- Include calculations in decision-making
- Prepare for presentation

2023/10/13 Advising Meeting 4

Kendra Besser - Nov 16, 2023, 5:24 AM CST

Title: Advising Meeting 4

Date: 10/13/2023

Content by: Kendra Besser

Present: Max, Caspar, Jamie, Kendra, Dr. Trevathan

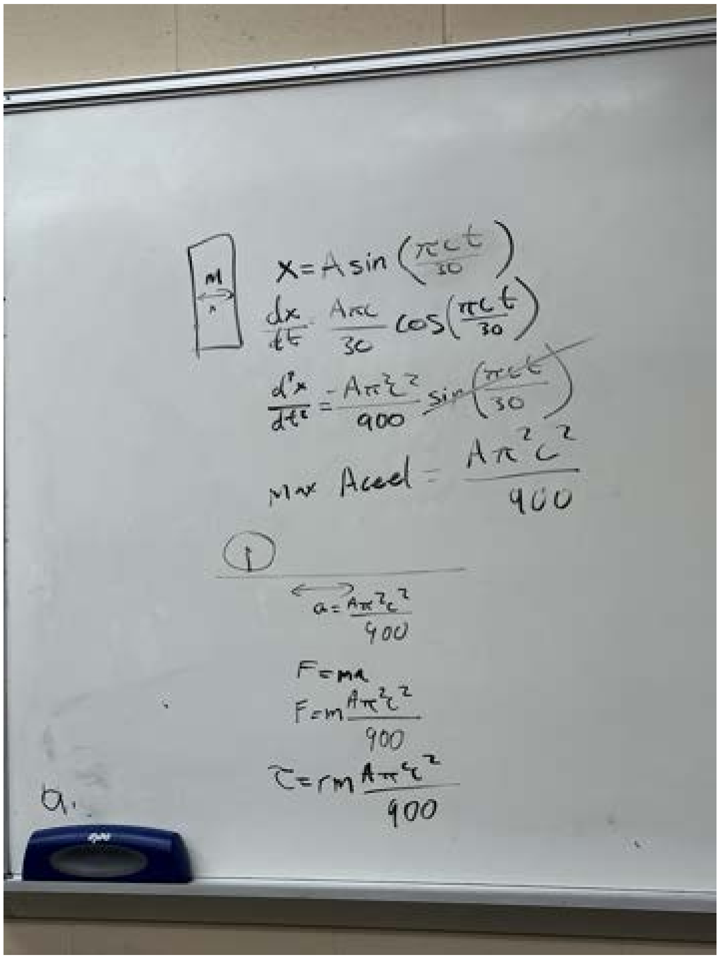
Goals: discuss torque equations and preliminary deliverables

Content:

equations:

- we calculated the acceleration from angular velocity x sin wave
- 1-1 gear ratio
- we are trying to solve for max torque

- we have mass m (phantom and platform)
- distance A =3 cm
- frequency f
  - 8 cycles per min = c
  - f in cycles per sec
- starting x position is x=A sin ((pi C t)/30)
  - take derivative - velocity (online) x'= Api c/30 cos(pi c t /30)
  - take derivative again - acceleration x''=-A (pi)^2 c^2 /900 sin(pi c t/30)
    - max acceleration = (A pi^2 c^2) /900 = 0.021 m/s^2
- torque required for max acceleration
  - F=m a = 0.189
  - mass in kilograms
  - T= r F
    - r is center of motor to top of gear on rack and pinion
- overall design good - works for required torque



fabrication

- 3d print parts, plastic rod
- glass ball bearings
- 3D print test pieces (critical dimensions) such as gears, before full print
    - adjustment variables

control of motor

- look into motor software and hardware to make sure it works
- program this in as a position (convert to rotational angle)

Conclusions/action items:

Begin fabrication and start testing motor control. The positioning sinusoidal wave (in meters) will be x=00.3sin(π(4/15)t). The torque needed is within the limits of the ultrasonic motor.

2023/10/20 Advising Meeting 5

Amber Schneider - Oct 20, 2023, 1:49 PM CDT

Title: Advising Meeting 5

Date: 10/20/2023

Content by: Amber Schneider

Present: Max, Caspar, Jamie, Kendra, Amber, Dr. Trevathan

Goals: discuss

Content:

PDS & Preliminary Report

- Graded
- Improve background
  - what problem does this solve? what is the purpose of the research? why does our product need to exist?
  - picture of motion in MRI scan
  - understanding of what the problems with motion in MRI scan is
- Project is straightforward, not a lot to go wrong

Updates - prototyping

- Split into 2 groups
  - Motor Control
    - Comes with initial code
    - worked to program with our own files
  - SOLIDWORKS
    - finalize gearbox assembly
    - scaled down version
    - work to 3D print at Makerspace
    - Need to add pinion, motor assembly
- Need to source long, plastic rod
  - potentially find in ECB
  - otherwise order

Conclusions/action items:

Try to 3D print parts by next week. Focus on creating our own program.

2023/10/27 Advising Meeting 6

Amber Schneider - Oct 27, 2023, 1:44 PM CDT

Title: Advising Meeting 6

Date: 10/27/2023

Content by: Amber Schneider

Present: Max, Caspar, Jamie, Kendra, Amber, Dr. Trevathan

Goals: discuss previous week, plan for next week

Content:

3D Printing

- printed gears
- currently printing gearbox

Drive Shaft

- plastic
    - pvc pipe?
- carbon fiber
- length is a concern

Linear Slides

- provided plastic linear slides
- hard to find online
- might be beneficial to talk with client

Materials

- ordering from approved vendor
- can order outside of approved vendors if there is no option
- client can buy for us to work around
- could use metal for testing, then swap out parts

Software

- got the program to run on mbed
- trying to create sinusoidal motion

Conclusions/action items:

Set up meeting with client to discuss use of Aluminum or other metals. Show & Tell is next week, will be in the same room & with the same groups as preliminary presentation. Prepare prototype, come up with questions.

2023/11/17 Advisor Meeting 7

Amber Schneider - Nov 17, 2023, 1:50 PM CST

Title: Advisor Meeting 7

Date: 11/17/2023

Content by: Amber Schneider

Present: Caspar, Jamie, Max, Kendra, Dr. Trevathan

Goals: discuss past few weeks of progress

Content:

- Show and Tell
    - good overall
    - discussed materials
    - discussed C & Mbed
- Mechanical
    - update on rails
        - coming next week
    - drive shaft ordered
    - meeting with client
        - no metal in MRI room
    - prototype can be built after rails come in
- Software
    - got functioning sinusoidal function
    - working to improve user interface

Conclusions/action items:

Next Meeting: discuss plans for statistical analysis, discuss potential testing results, show finished prototype, show procedures for future tests.

2023/12/1 Advisor Meeting 8

Kendra Besser - Dec 01, 2023, 1:51 PM CST

Title: Advisor Meeting 8

Date: 12/1/2023

Content by: Kendra Besser

Present: Caspar, Jamie, Max, Amber, Dr. Trevathan

Goals: discuss past few weeks of progress

Content:

- showed what materials we have and how it will be assembled
- explained that we need the adapter and screws
- discussed the encoder testing went well and the rpm is going to be tested
- testing plans
  - one revolution making sure the starting and stopping spot is the same
  - do video footage and going frame by frame to ensure plotting (make sure we do this with different weights)
- statistical analysis
  - mean error from recreated sinusoid
  - make sure timing matches with code
  - ensure the sinusoid does not deviate across different weights!!! - most important
  - period of a cycle and do statistical test to what is in the code
- errors - discus what it is and how to solve for it
- can send poster to James before Wednesdays for feedback
- final report improvements
  - more detailed
  - detail on test procedures and how we did statistical analysis
  - how outcomes meet the PDS
  - quantitative analysis on why we made design decisions
  - explain design process in design matrix
- talked about how we agree there is more work to be done in another semester

Conclusions/action items:

This was the final meeting before presentation day. We can send our poster in ahead of time for feedback.

2023/09/29-Evaluation of Design Ideas

Jamie Flogel - Oct 10, 2023, 8:12 PM CDT

Title: Evaluation of Design Ideas

Date: 9/29/2023

Content by: Jamie

Present: Entire Team

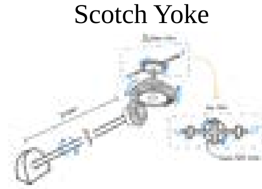
Goals:

-Discuss individual design ideas and evaluate them

Content:

-We met to discuss which design ideas we want to go forward with

-We decided our top three contenders are the lead screw, rack and pinion, and scotch yoke

Categories	Lead Screw 		Scotch Yoke 		Rack & Pinion 	
Efficiency (25)	2/5	10	4/5	20	5/5	25
Accuracy (20)	5/5	20	3/5	12	4/5	16
Ease of Fabrication (15)	2/5	12	4/5	12	3/5	12
Cost (15)	4/5	12	3/5	9	2/5	6
Adjustability (10)	5/5	10	2/5	4	4/5	8
Safety (10)	4/5	8	2/5	4	4/5	8
Durability (5)	1/5	1	4/5	4	4/5	4
Total (100)		73		65		**79**

Design Criteria

- **Efficiency (25)**
  - The percent of power translated from rotational to linear motion
    - 97% for Rack & Pinion, 20-80% Lead Screw, 75% Scotch Yoke
- **Accuracy (20)**
  - How precise can the movement be within 1 waveform?
    - Lead screw limited by pitch

        - Scotch Yoke limited by length of the yoke
        - Rack and Pinion limited by gear teeth width
- **Ease of Fabrication (15)**
    - Off-the-shelf, non-complex, easy to assemble
        - We would have to printer a screw vertically so we are limited by size and availability of 3D printers
        - Rack and pinion requires a higher degree of precision when printing than the Scotch and Yoke design
- **Cost (15)**
    - Materials, fabrication, supporting pieces, both amount of materials and cost of materials
        - Lead screw requires the least material/least amount of parts
        - Rack and pinion requires the most amount of material
- **Adjustability (10)**
    - How adjustable is the design between different waveforms?
        - Lead screw can best adapt to different waveform
        - Would be less convenient to have to change out scotch yoke piece with different radii for different amounts of motion
- **Safety (10)**
    - Exposed moving pieces? The ability for the system to be MR-compatible and prevent user injury
        - Scotch yoke requires motion in multiple directions which poses the biggest potential safety concern
- **Durability (5)**
    - Evaluates the device's wear proportionally to its time in use.
        - Lead screw has a higher wear rate than the other designs
        - Ball bearing reduces wear rate on the Scotch Yoke design

Conclusions/action items:

We will plan to go forward with the rack and pinion design. This will be separated from the motor by a 2m drive shaft to reduce signal noise on the MRI scans. We will make any modifications to our decisions as we continue throughout the design process.

2023/10/20 Team Solidworks Gearbox Assembly

Jamie Flogel - Dec 12, 2023, 9:05 PM CST

Title: Meeting notes

Date: 10/20/2023

Content by: Jamie, Max

Present: Caspar

Goals:

-Work on Solidworks of preliminary design

Content:

-We discussed current solidworks models and how to improve/integrate into assembly

-Discussed 3D printing of the first prototype

-Full assembly and files attached below

-We discussed waiting on 3D printing to ensure makerspace account is set up with client

-Plan to 3D print early next week

Conclusions/action items:

We met to work on the Solidworks design of the gearbox assembly. We will move forward with 3D printing once we set up proper funding.

MAXWELL NASLUND - Oct 20, 2023, 1:25 PM CDT

Download

BallBearing.SLDPRT (99.7 kB)

MAXWELL NASLUND - Oct 20, 2023, 1:26 PM CDT

Download

BevelGear_1.SLDPRT (681 kB)

MAXWELL NASLUND - Oct 20, 2023, 1:26 PM CDT

Download

crosspin.SLDPRT (123 kB)

MAXWELL NASLUND - Oct 20, 2023, 1:26 PM CDT

Download

gearbox.SLDPRT (138 kB)

MAXWELL NASLUND - Oct 20, 2023, 1:26 PM CDT

Download

metric_gear.SLDPRT (263 kB)

MAXWELL NASLUND - Oct 20, 2023, 1:26 PM CDT

Download

New_Gearbox.SLDASM (587 kB)

MAXWELL NASLUND - Oct 20, 2023, 1:26 PM CDT

Download

rail.SLDPRT (155 kB)

MAXWELL NASLUND - Oct 20, 2023, 1:26 PM CDT

Download

slide.SLDPRT (117 kB)

2023/10/27-Mechanical Team Meeting

Jamie Flogel - Dec 12, 2023, 9:11 PM CST

Title: Meeting Notes

Date: 10/27/2023

Content by: Jamie

Present: Max, Caspar

Goals:

-Continue to improve mechanical aspects of design

Content:

-Continued to make modifications to the gearbox assembly

-Discussed potential options for a driveshaft

-Discussed potential options for linear rails

-Updated tolerances on gearbox so that glass ball bearings fit better

Conclusions/action items:

We will meet with the our client to discuss our options for linear rails due to limitations of non-metal options.

2023/11/01 Show & Tell Prep

Amber Schneider - Nov 08, 2023, 12:37 PM CST

Title: Show & Tell Prep

Date: 11/1/2023

Content by: Amber Schneider

Present: Max, Kendra, Caspar, Jamie

Goals: outline pitch and call to action for Show and Tell

Content:

Pitches consist of these main elements

- Call to action - start here to catch your audience's attention.
    - What are you looking for or need help on?
    - What do you want to get out of this event and how can your peers help you?
    - This can evolve as the session progresses and you gather more feedback. Be prepared to adjust based on your audience and the solutions you receive from your peers.
- Demonstrate using your physical prototype/representation to illustrate your need
- Other elements that might be needed to provide context to your call to action:
    - What's the Problem? (this should be extremely brief)
    - What's your solution / major benefit?
    - What progress have you made? / What are your upcoming milestones?

'Call to action' ideas

- How do you use a specific tool needed for the design?
- How will you manufacture the device/solution?
- How will you test it to ensure it meets the PDS? Or specific PDS criteria?
- How will a user interact with the design?
- How are you going to commercialize (market, sell, etc.) it?
- What's the market opportunity?
- What makes this unique or defensible? Can I copy it? Does it stand out? Is it interesting in some way?

<u>What's the Problem:</u>

- Tissue phantoms used to test and calibrate qMRIs are often static models of the human body. These static models do not effectively represent the constant motion created from natural processes such as respiratory and digestive functions. To solve this, an MR-compatible device that can hold a phantom and simulate the physiological movements will be created for qMRI evaluations.

<u>What's the solution?</u>

- MR safe ultrasonic motor, programmed to move stage in sinusoidal motion, bevel gears translate the rotational motion to linear motion and movement is controlled by a rack and pinion connected to the platform. Platform slides with reduced friction on linear slides

<u>What Progress/Upcoming Milestones?</u>

- Gearbox
    - We modeled the design fully in solidworks

    - We began 3D printing and have fully printed the gears
    - We have an initial print of the gearbox
    - We are ordering more linear rails
    - We are going to order a rod for the drive shaft soon
    - Once we have all the components we will assemble them and begin preliminary testing
- Motor
    - Acquired ultrasonic motor from client
    - Ran pre-programed file on Termite
        - Rotate continuously at a specific RPM
        - Rotate a specific amount of degrees
    - Downloaded mbed to alter file
        - C++
    - Currently working on programming a sinusoidal function
    - Future work:
        - Refine sinusoidal wave approximation
            - How to use the time function in C++?
        - How to use user input from the terminal?
        - Implement other functions/ features that would be useful

Call to action Ideas:

- Ideas for wearing down the slides/making them slide smoothly
- Drive shaft
- Any experience with mbed/C++?
    - User input from terminal (mbed)

Conclusions/action items:

The team is prepared to explain the progress we have made since preliminary presentation to other groups. We have written an outline of what we want to cover. Additionally, we have brainstormed what "call to action" items we want feedback on from other students.

2023/11/02-Updated Gearbox SolidWorks

MAXWELL NASLUND - Nov 02, 2023, 5:38 PM CDT

Title: Updated Gearbox SOLIDWORKS

Date: 11/2/2023

Content by: Jamie and Max

Present: N/A

Goals:

-Document updates to SOLIDWORKS design

Content:

-We made the gearbox slightly larger to accommodate a larger pin hole on the gears

-With a larger hole in the gears we hope to be able to 3D print a 5 mm screw to secure the gears to the rod

-We also extended the legs so that they can support the entire length of the linear slides

-Since the 3D printer cannot accommodate super long legs we split them into two pieces we can connect via 3D printed screws

-Gears should still align properly in the slightly larger gearbox

-New SOLIDWORKS files are attached below

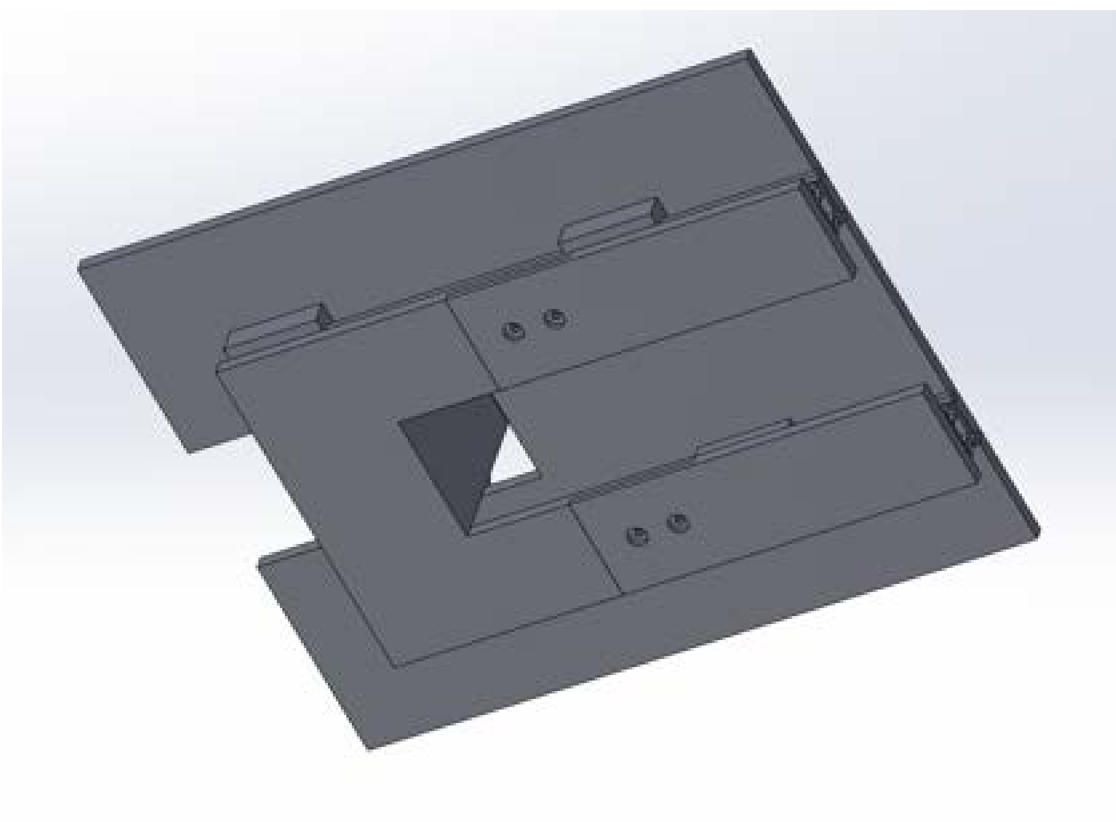


Figure 1: Bottom

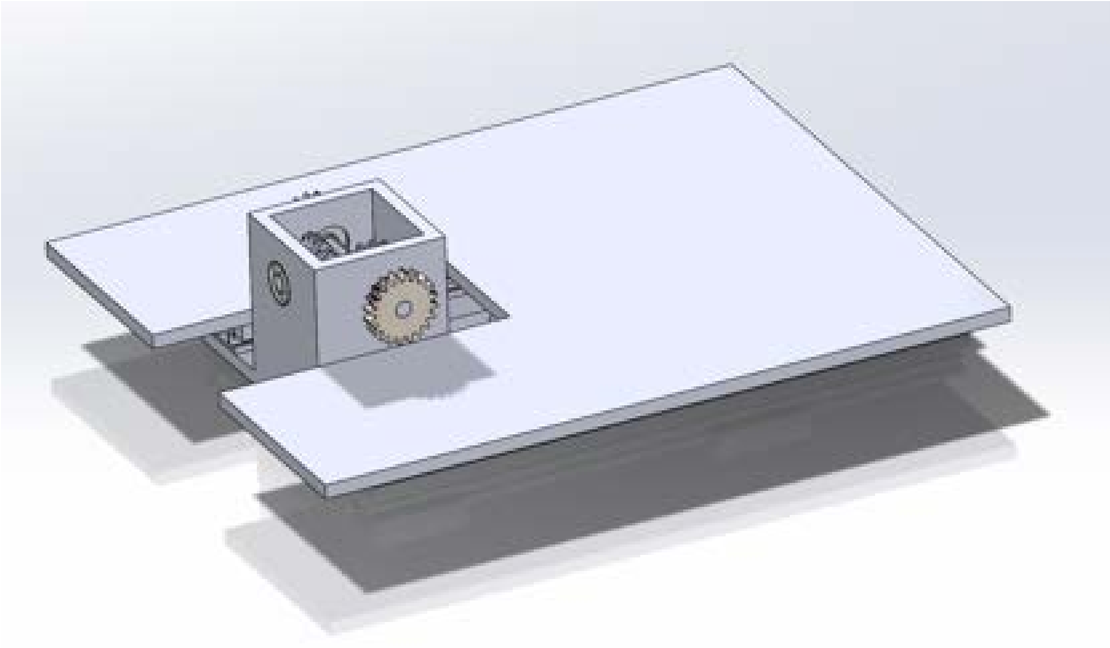


Figure 2: Top

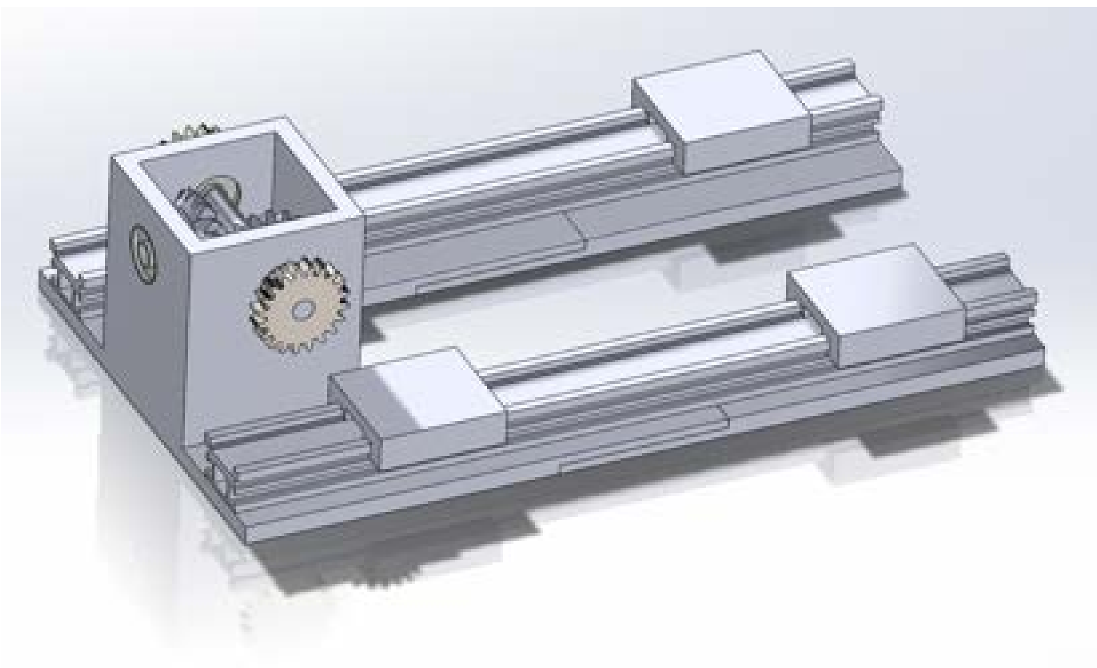


Figure 3: No Platform

Figure 4: Gearbox View

Conclusions/action items:

We will continue to edit and update the solidworks as needed. We will continue to 3D print to develop a better model of our design.

MAXWELL NASLUND - Nov 02, 2023, 5:41 PM CDT

Download

BevelGear_1.SLDPRT (706 kB)

MAXWELL NASLUND - Nov 02, 2023, 5:42 PM CDT

Download

extension.SLDPRT (102 kB)

Amber Schneider - Nov 03, 2023, 1:32 PM CDT

Download

crosspin.SLDPRT (137 kB)

MAXWELL NASLUND - Nov 02, 2023, 5:42 PM CDT

Download

gearbox.SLDPRT (173 kB)

MAXWELL NASLUND - Nov 02, 2023, 5:42 PM CDT

Download

GearboxAssem.SLDASM (383 kB)

MAXWELL NASLUND - Nov 02, 2023, 5:42 PM CDT

Download

metric_gear.SLDPRT (279 kB)

MAXWELL NASLUND - Nov 02, 2023, 5:42 PM CDT

Download

NewPlatform.SLDPRT (98.5 kB)

MAXWELL NASLUND - Nov 02, 2023, 5:42 PM CDT

Download

rail.SLDPRT (165 kB)

MAXWELL NASLUND - Nov 02, 2023, 5:42 PM CDT

Download

slide.SLDPRT (148 kB)

MAXWELL NASLUND - Nov 02, 2023, 5:45 PM CDT

Download

BevelGear_1.STL (266 kB)

MAXWELL NASLUND - Nov 02, 2023, 5:45 PM CDT

Download

crosspin.STL (49.4 kB)

MAXWELL NASLUND - Nov 02, 2023, 5:45 PM CDT

Download

extension.STL (31.1 kB)

MAXWELL NASLUND - Nov 02, 2023, 5:45 PM CDT

Download

gearbox.STL (94.5 kB)

MAXWELL NASLUND - Nov 02, 2023, 5:45 PM CDT

Download

metric_gear.STL (79.8 kB)

2023/11/03 Show & Tell Notes

Amber Schneider - Nov 08, 2023, 12:40 PM CST

Title: Show & Tell Notes

Date: 11/3/2023

Content by: Amber Schneider

Present: Kendra, Caspar, Jamie

Goals: Document Show and Tell feedback from other students

Content:

Group A: Jamie, Kendra

Group B: Amber, Caspar

- Non-Magnetic Materials
    - Acrylics
        - 3D printing? - there may be cad models already mode
    - Polycarbonate
    - Glass/
        - Silicone-based
    - Ceramics
    - Resin
        - Reduce ridges, texture
        - Rigid 4K
            - Stiff
            - Makerspace may have it
    - High sensitive acrylic carbon in teamlabs (3D model and carve it out) 1002 lab laser cutter
    - Closed system slider with lubricant inside
    - Wheels on the tract rather than slider
    - Drive shaft materials
        - Good shear resistance
        - Thick rubber?
    - *What material are the linear slides made of?*
- Get input from terminal
    - PuTTy
    - VS Code
    - STDin libraries in c++ ?? very confused on what they were saying
    - Keal IDE
- Reducing wear
    - Coating the PLA with a material to extend Shelf life
    - Bushing material between PLA elements
    - Way to reduce friction on the teeth
    - Sanding down the rails
    - Redesign the sliders
    - *What kind of solid lubricant do the linear slides use?*

Conclusions/action items:

The team met with other students on Friday during Show & Tell. We got feedback in 3 main categories: Non-magnetic materials, Getting input from terminal, Reducing Wear. The team will evaluate this feedback in the coming weeks to improve the current prototype.

2023/11/17 - Platform Drawing

Jamie Flogel - Dec 12, 2023, 9:15 PM CST

Title: Platform Drawing

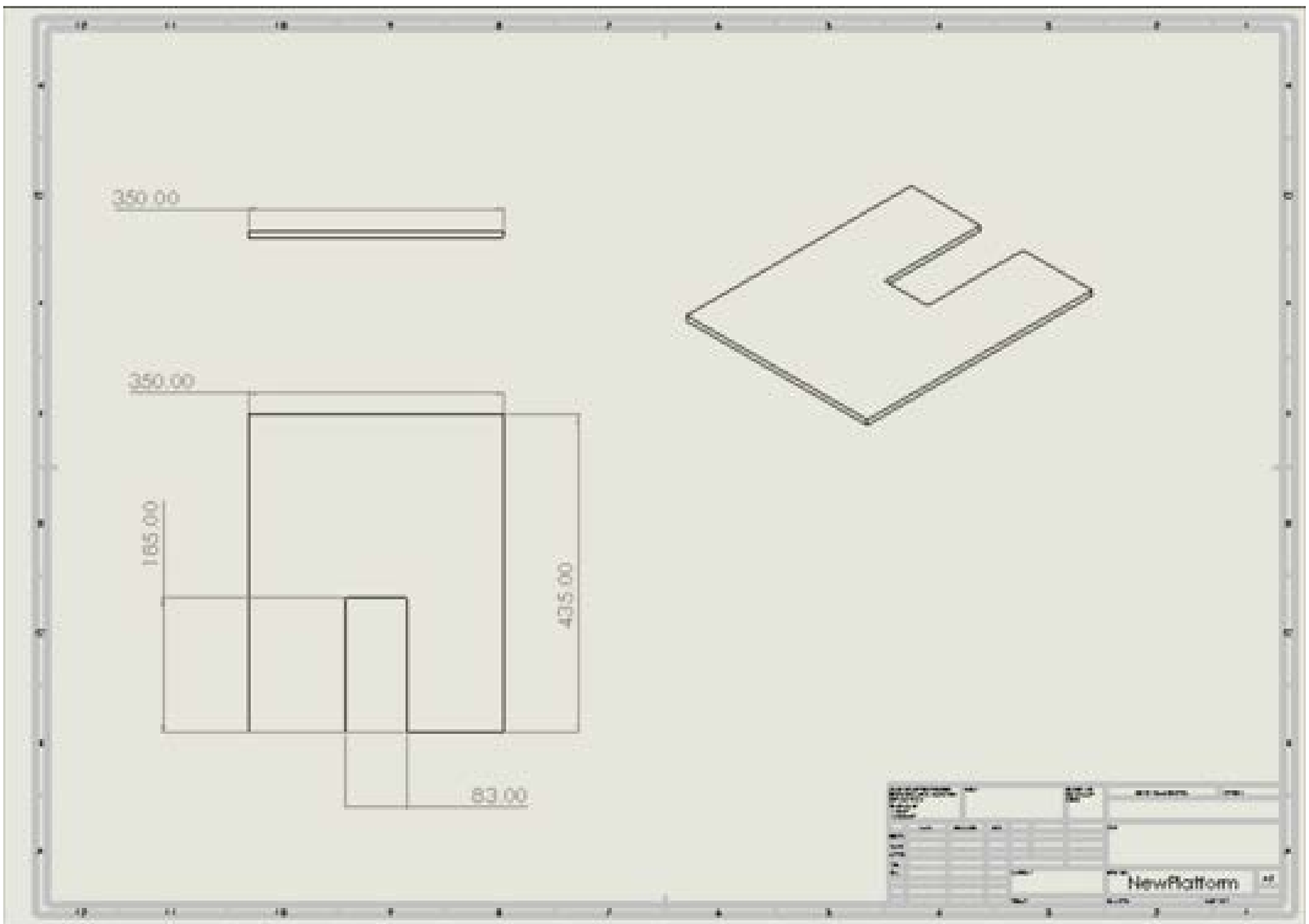
Date: 2023/11/17

Content by: Max, Jamie

Present: n/a

Goals: Outline the critical dimensions of the phantom platform.

Content:



Conclusions/action items:

We will fabricate the platform using a 1/4 in thick acrylic sheet from the makerspace. We will cut this to the specified dimensions in the TEAMLab.

2023/11/17 - Driveshaft support stand

Jamie Flogel - Dec 12, 2023, 9:17 PM CST

Title: Driveshaft Support Stand

Date: 2023/11/17

Content by: Max, Jamie

Present: n/a

Goals: Outline the files required to 3d print the Driveshaft support stand components

Content:

Attached are the .STL files

-We developed a support piece to support the driveshaft between the motor stand and the gearbox

-Since the driveshaft is ~5ft long this will keep it from bending

Conclusions/action items:

We will 3D print this and add glass ball bearings on the arms to properly support the driveshaft.

MAXWELL NASLUND - Nov 17, 2023, 2:39 PM CST

Download

driveshaft_stand_bottom.SLDPRT (89 kB)

MAXWELL NASLUND - Nov 17, 2023, 2:39 PM CST

Download

driveshaft_stand.SLDPRT (91.1 kB)

MAXWELL NASLUND - Nov 17, 2023, 2:39 PM CST

Download

driveshaft_stand_bottom.STL (2.68 kB)

MAXWELL NASLUND - Nov 17, 2023, 2:39 PM CST

Download

driveshaft_stand.STL (16.9 kB)

2023/12/01 - Motor Stand

Jamie Flogel - Dec 01, 2023, 3:11 PM CST

Title: Motor Stand

Date: 12/1/2023

Content by: Jamie and Max

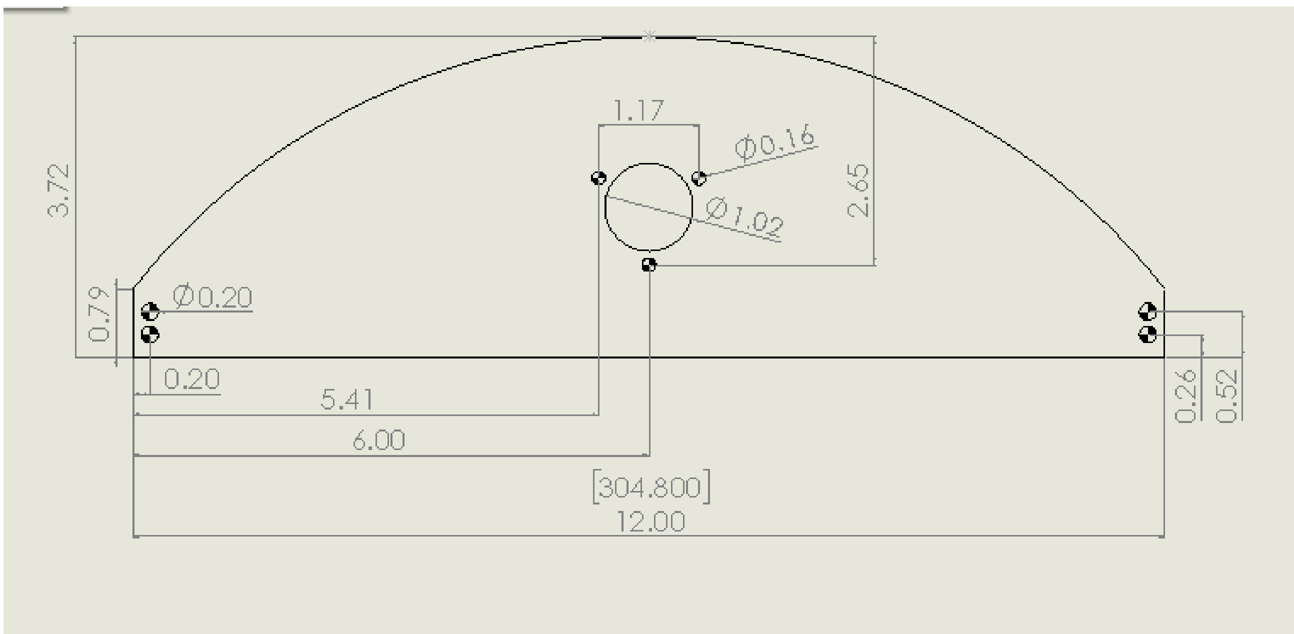
Present: N/A

Goals:

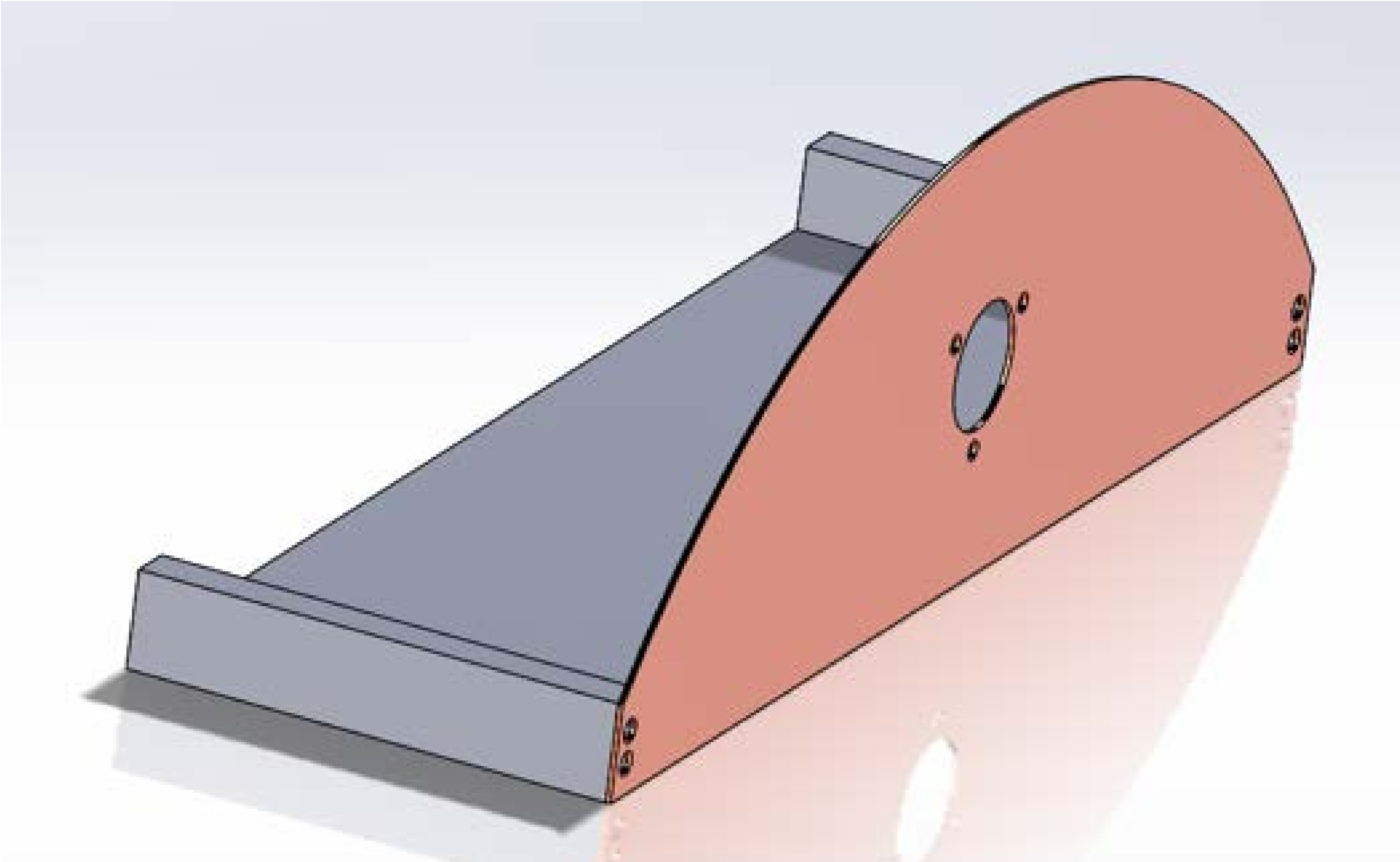
-Develop a stand to hold the motor in the right position at the right height

Content:

Drawing of copper piece:



Assembly of plastic and copper piece:



Conclusions/action items:

We will 3D print the plastic piece and machine the copper piece so that we can attach the motor

Jamie Flogel - Dec 01, 2023, 3:12 PM CST

Download

MotorCopperFace.SLDPRT (125 kB)

Jamie Flogel - Dec 01, 2023, 3:12 PM CST

Download

MotorStand.SLDPRT (101 kB)

Jamie Flogel - Dec 01, 2023, 3:12 PM CST

Download

MotorStand.STL (46.7 kB)

Jamie Flogel - Dec 01, 2023, 3:12 PM CST

Download

MotorCopperFace.SLDDRW (127 kB)

2023/09/29-BPAG Meeting Notes

Jamie Flogel - Sep 29, 2023, 12:24 PM CDT

Title: BPAG Meeting Notes

Date: 9/29/2023

Content by: Jamie

Present: N/A

Goals:

-Learn more about expectations for the financial aspects of our project

Content:

-Get client to buy things for you or pay and get reibursed

-Have to have all expenses approved by client prior to purchase

-If over $1000 we must get department approval

-Make sure to keep track of purchases

-Original receipts in the notebook

-Table of expenses in notebook, progress report and all reports

-Our client is affiliated with UW

-Could use UW funds

-If personal funds then you can buy anything

-If using UW funds must follow certain rules

-Use ShopUW+ if UW funds or through Makerspace, TEAMLab or other UW services

-Paying ourselves with UW Funds is a last resort

-Use list of vendors from ShopUW+ and provide client with part numbers to order

-Be careful using Newark because their website is difficult to navigate so look elsewhere and copy/paste part numbers

-MSC and Grainger good for parts and plastics - or look at TEAMLab (just go down there)

-If using the makerspace the client can set up and account with a funding string

-At makerspace we would complete the team information excel sheet for our client with naming file BMEDesign_MRI

-The shop fee at the makerspace/TEAMLab is our responsibility not the client

-Can meet with TEAMLab/Makerspace for expertise and appointments can be made online

-Cannot take TEAMLab tools out of ECB must work downstairs

-Only BPAG should seek reimbursement

-Start reimbursement should start before poster session

-You have 90 days after purchase to get reimbursed

-Need a detailed receipt not just a screenshot of cart

-Amazon - download an invoice

-Need date, purchaser name, vendor details, itemized (item(s) details and quantity) , cost each, total cost

-It can take 3+ weeks to get reimbursed

-TEAMLab is free this semester

-Poster printing expenses are our responsibility

-Table should include all of the info vital to purchase again

-Make sure links are clickable

-Shrink links

-Can break up table into categories

-Can have a different table of just the final design in case we don't end up using all components

-With UW funds even if it's more expensive we are required to buy through our vendors

-Most ShopUW items are free shipping

Conclusions/action items:

Since our client is affiliated with UW they will likely use UW funds and should pay. They must follow UW rules and buy through approved outlets. I will keep through records of any purchases in the appropriate places.

2023/11/02- Expense Table

Jamie Flogel - Nov 02, 2023, 4:54 PM CDT

Title: Expense Table

Date: 11/02/2023

Content by: Jamie

Present: N/A

Goals:

-Document expenses

Content:

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Component 1								
Ultimaker PLA (37.0 g)	3D printed gears to translate and facilitate motion	Ultimaker	RAL-9010	10/26/2023	1	$2.96	$2.96	N/A
Component 2								
N/A								
Component 3								
N/A								
TOTAL:	**$2.96**							

Conclusions/action items:

So far our only expense has been 3D printing the gears. We will need to do more 3D printing in the future as well as ordering more linear slides and a drive shaft.

2023/12/12-Final Expense Table

Jamie Flogel - Dec 12, 2023, 8:59 PM CST

Title: Final Expense Table

Date: 12/12/2023

Content by: Jamie

Present: N/A

Goals:

-Establish and document all expenses from the semester

Content:

-We were provided the motor, some linear rails and sliders

Expenses

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Component 1								
Ultimaker PLA (37.0 g)	3D printed gears to translate and facilitate motion	Ultimaker	RAL-9010	10/26/2023	1	$2.96	$2.96	N/A
Ultimaker PLA (325.0 g)	3D printed gears and gearbox	Ultimaker	RAL-9005	11/03/2023	1	$26.00	$26.00	N/A
Bamboo Labs PLA (127.34 g)	3D printed gearbox extension pieces	Bambu Lab	#000000	11/15/2023	1	$12.19	$12.19	N/A
Ultimaker PLA (118 g)	3D printed support for the driveshaft	Ultimaker	RAL-9005	11/17/2023	1	$9.44	$9.44	N/A
Ultimaker PLA (27 g)	3D printed racks	Ultimaker	RAL-9005	11/29/2023	1	$2.16	$2.16	N/A
Ultimaker PLA (126 g)	3D printed Motor Stand	Ultimaker	RAL-9005	12/01/2023	1	$10.08	$10.08	N/A

Component 2								
Linear Rails	400 mm linear rails	igus	CWS-06-30-400	11/13/2023	2	$167.69	$335.38	Link
Component 3								
Linear Slides	Slides to support platform on linear slides	igus	WWPL-06-30-06	11/13/2023	2	$18.25	$36.50	Link
Component 4								
Driveshaft	Connection piece between motor and gearbox	Grainger	H0400075PW1000	11/16/2023	1	$8.00	$8.00	Link
Component 5								
Platform	1/4 black acrylic sheet provided by Makerspace	MSC	MSC# 63391700 (no part number given similar example)	11/17/2023	1	$20.00	$20.00	N/A
Component 6								
Glass Ball Bearings	Glass ball bearings to allow for frictionless rotation	Grainger	MSN0459939	12/1/2023	5	$17.07	$85.35	N/A
Component 7 - unused features due to reprints/redesigns								
Ultimaker PLA	3D printed Gearbox	Ultimaker	RAL-9005	10/26/2023	1	$19.36	$19.36	N/A
Ultimaker PLA	Motor to driveshaft adapter piece	Ultimaker	RAL-9005	12/1/2023	1	$1.12	$1.12	N/A

Ultimaker PLA	Motor to driveshaft adapter piece reprint	Ultimaker	RAL-9005	12/4	1	$2.84	$2.84	N/A
Ultimaker PLA	Motor to driveshaft adapter piece reprint	Ultimaker	RAL-9005	12/5	1	$2.65	$2.65	N/A
TOTAL:	**$574.03**							

Conclusions/action items:

Overall we stayed within budget so far this semester. We will continue to update the expense table as we continue to make purchases for the project.

2023/12/14 - Final Prototype Fabrication Protocol

MAXWELL NASLUND - Dec 14, 2023, 7:48 PM CST

Title: Final Prototype Fabrication Protocol

Date: 223/12/14

Content by: Maxwell Naslund

Present: n/a

Goals: Outline how to fabricate the entirety of the final prototype

Content:

Motor Assembly

Copper Face

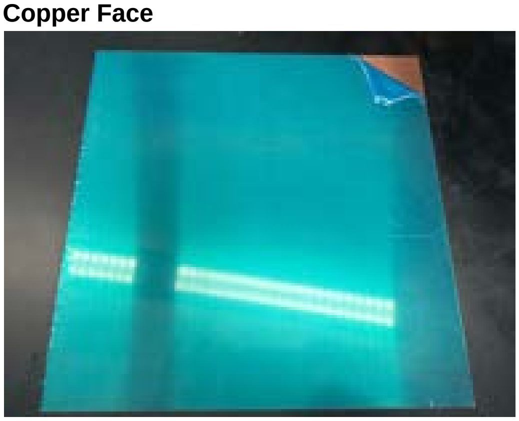


Figure 1: Uncut 1' x 1' copper sheet

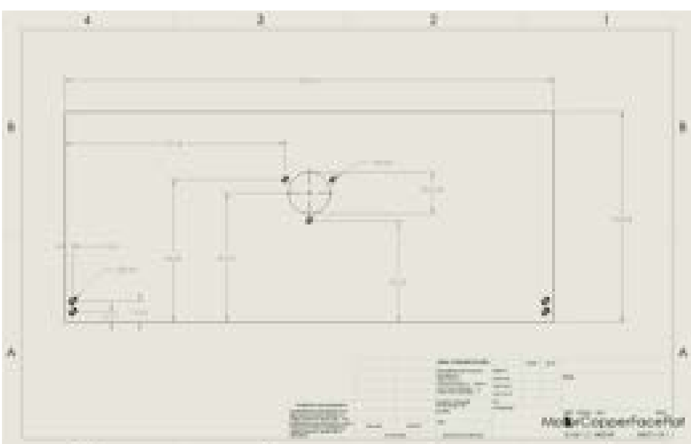


Figure 2: Copper face drawing

1. Starting from the 1' x 1' copper sheet illustrated in figure 1, on the metal shear in the. TEAM Lab, cut a piece to 130.58cm tall.
2. Drill a pilot hole in the cut copper sheet at 152.4mm in the x-dimension, and 88.84mm in the y-direction as illustrated in figure 2.
3. Using a 1" hole saw, drill a 1" hole centered at the previously drilled pilot hole.
4. Drill three 3mm holes 120 degrees apart around the previously drilled 1" hole as illustrated in figure 2.
5. Drill four 5mm holes at the locations illustrated in figure 2.

Motor Stand

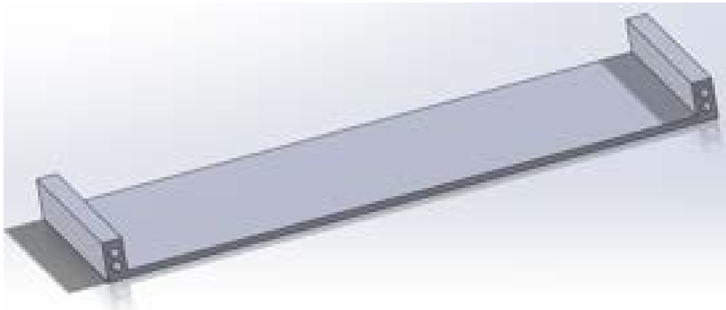


Figure 3: Motor stand SOLIDWORKS

1. 3D print attached motor stand .stl file at the Makerspace with 20% infill.

Motor to Driveshaft Adapter

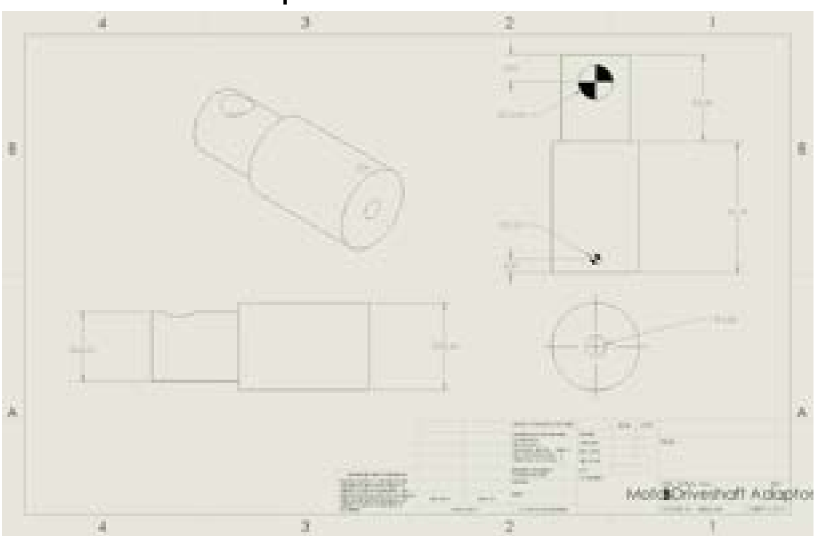


Figure 4: Driveshaft to Driveshaft Adapter drawing

1. Starting from 1” cylindrical aluminum stock, lathe one side down to a 20.07mm diameter 25.4mm in the TEAM Lab, as illustrated in figure 4.
2. Using a 6mm bit, drill a center hole 19mm deep on the side of the stock that is 25.4mm, as illustrated on figure 4.
3. Part the cylindrical aluminum stock off at 63.5mm, as illustrated in figure 4.
4. On the mill, drill a 3mm hole 4mm from the end of the 25.4mm end of the part. Drill down to the center hole drilled on the lathe, as illustrated on figure 4.
5. On the mill, drill a 10mm hole 8mm from the end of the 20.07mm end of the part. Drill all the way through the part, as illustrated on figure 4.

Full Motor Assembly

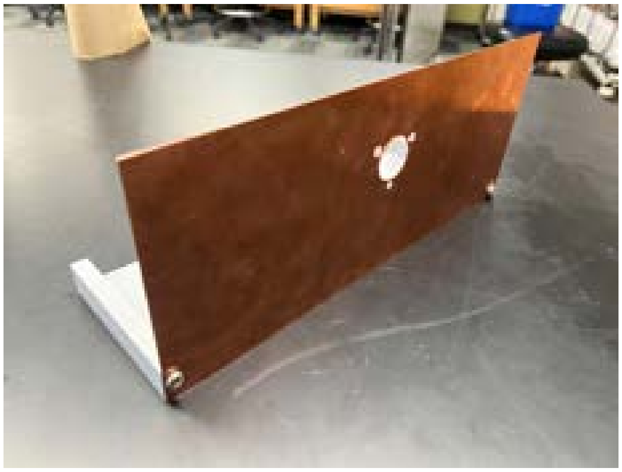


Figure 5: Motor stand and Face connected

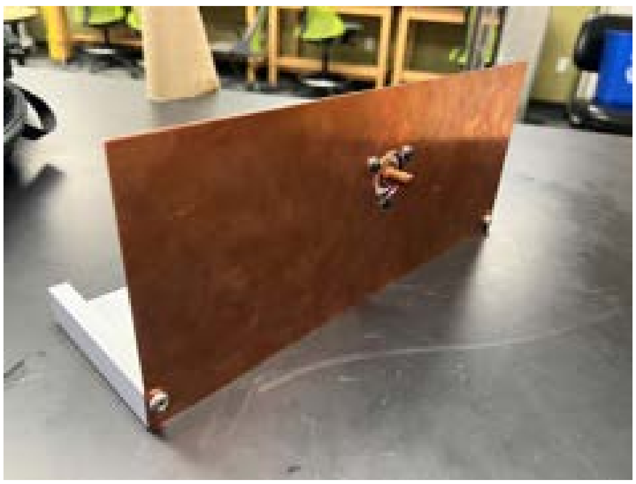


Figure 6: Motor connected to Motor stand

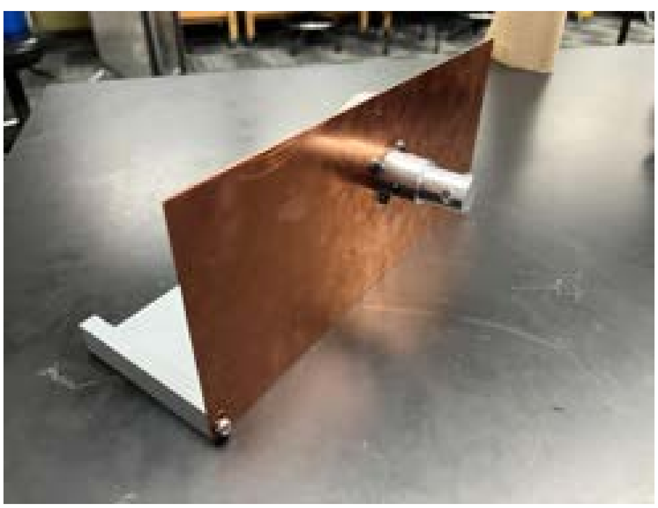


Figure 7: Motor to Driveshaft Adapter connected

1. Using two M5 screws, attach copper face to copper stand. One screw on each side staggered, as illustrated in figure 5.

2. Using three M4 and three M4 washers, connect the piezoelectric motor to the copper face. Motor cable connection should point down, as illustrated in figure 6.
3. Slide the Motor to Driveshaft Adapter over the motor stud. Using a M4 screw, screw down onto one of the two flat sides of the motor stud to secure the adapter to the motor, as illustrated in figure 7.

Gearbox Assembly

3D Print Components

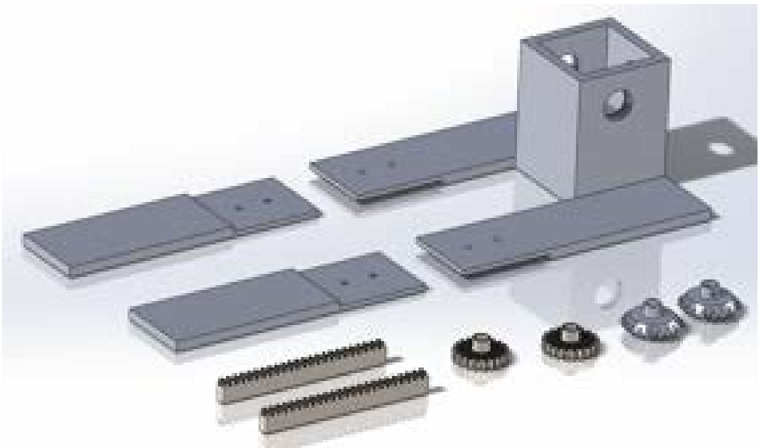


Figure 8: Gearbox 3D printed components

At the Makerspace, 3D print the Gearbox, Gearbox Extensions, Bevel Gears, Pinion Gears, and Rack Gears at 20% infill, as illustrated in figure 8.

Crosspin

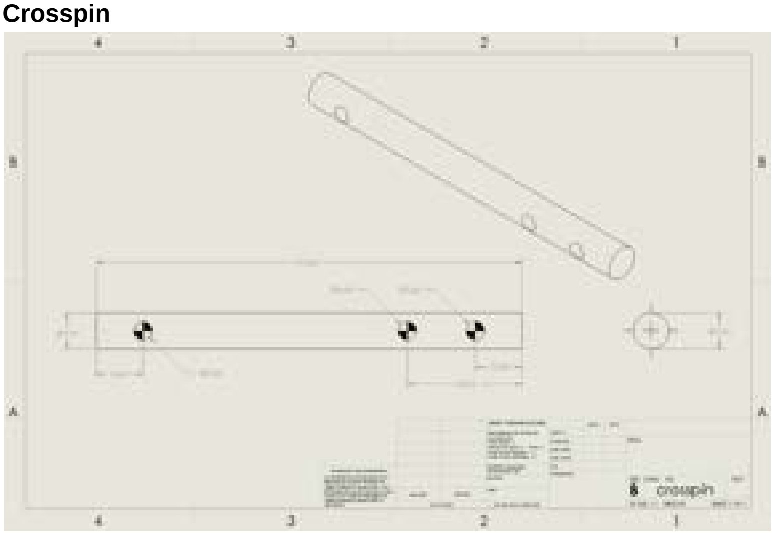


Figure 9: Crosspin drawing

1. In the TEAM Lab, start with 1” HDPE cylindrical stock. Lathe the piece down to 10mm diameter.
2. Using a 5mm bit, on the mill drill three holes in the crosspin in the locations illustrated in figure 9.

Gearbox to Driveshaft Adapter

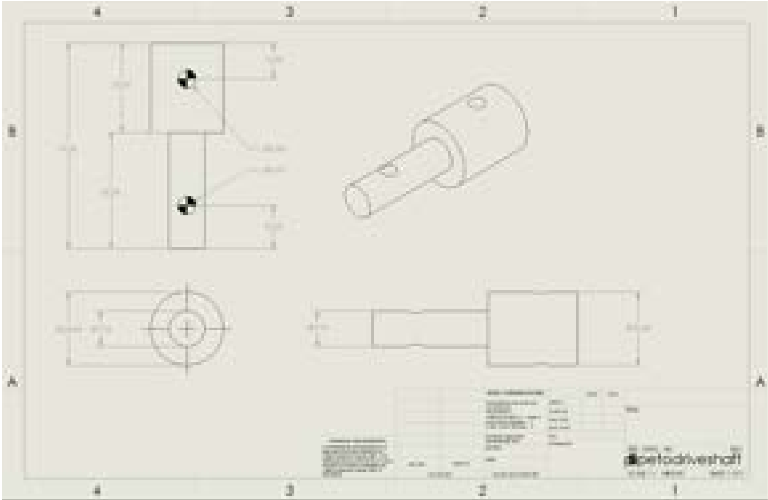


Figure 10: Gearbox to Driveshaft Adapter

1. In the TEAM Lab, start with 1" HDPE cylindrical stock. Lath 32.28mm length to 10mm diameter.
2. Lathe the next 25mm down to 20.4mm diameter.
3. Part the piece off to a 57.28mm length.
4. Using a 5mm bit, on the mill drill two holes in the adapter in the locations illustrated in figure 10.

Phantom Bed

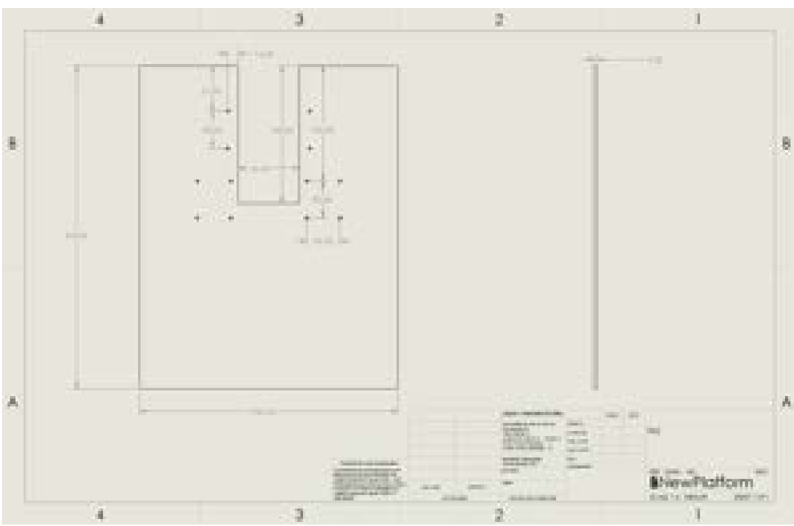


Figure 11: Phantom Bed drawing

1. In the TEAM Lab, cut an acrylic sheet to 350mm by 435mm on a table saw.
2. Using a bandsaw, cut a 83mm by 185mm rectangle from the center of the 350mm side, as illustrated in figure 11.
3. Using a drill press, drill 12 M4 holes according to the drawing illustrated in figure 11.

Full Gearbox Assembly

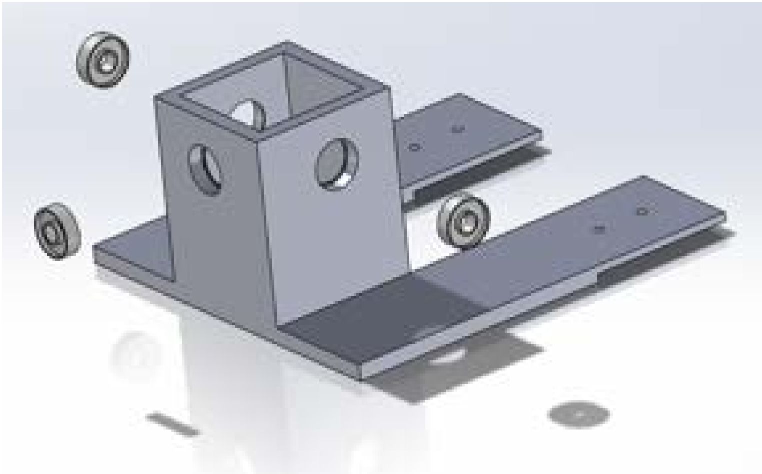


Figure 12: Adding bearings to gearbox

1. Insert three glass ball bearings into the gearbox as illustrated in figure 12.

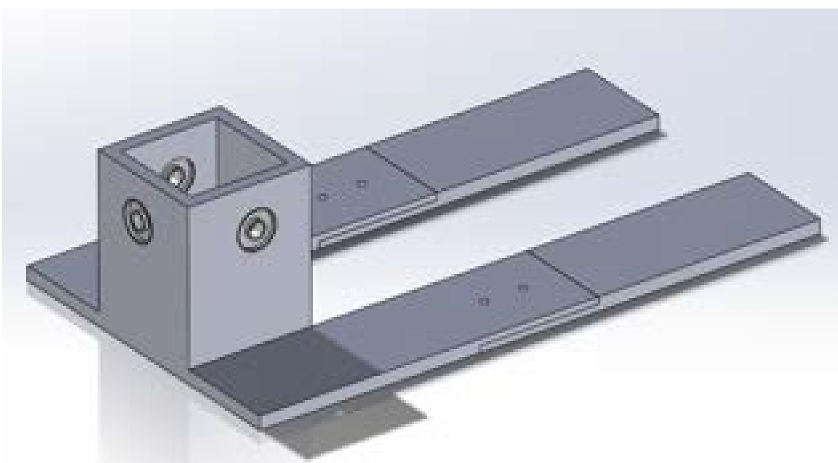


Figure 13: Adding Gearbox extensions

2. Connect 3D printed gearbox extension pieces to the gearbox via four M4 screws, as shown in figure 13. Screws should be screwed in from the bottom up.

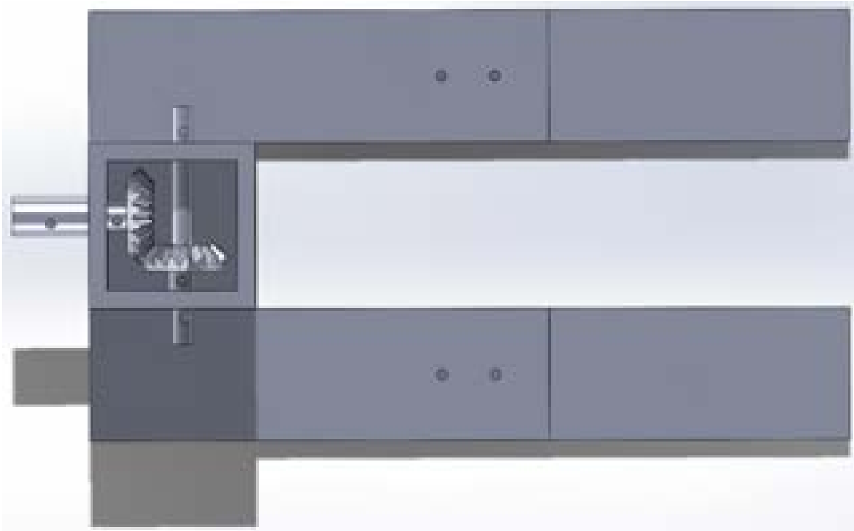


Figure 14: Adding internal components to gearbox

3. Add Gearbox to Driveshaft adapter, Crosspin, and bevel gears in the configuration illustrated in figure 14.
4. Using two M4 screws, anchor the bevel gears to the crosspin and adapter.

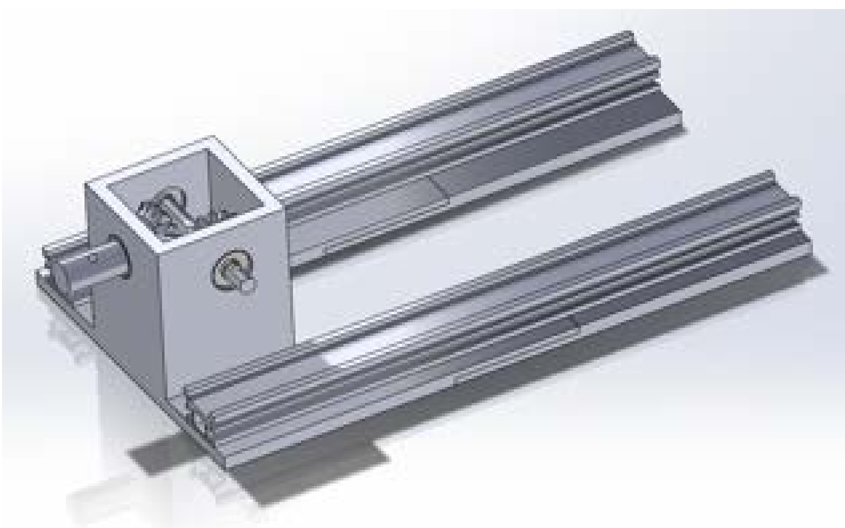


Figure 15: Adding linear rails to assembly

5. Using the same four M4 screws to connect the gearbox to the gearbox extensions, connect two linear rails as illustrated in figure 15.

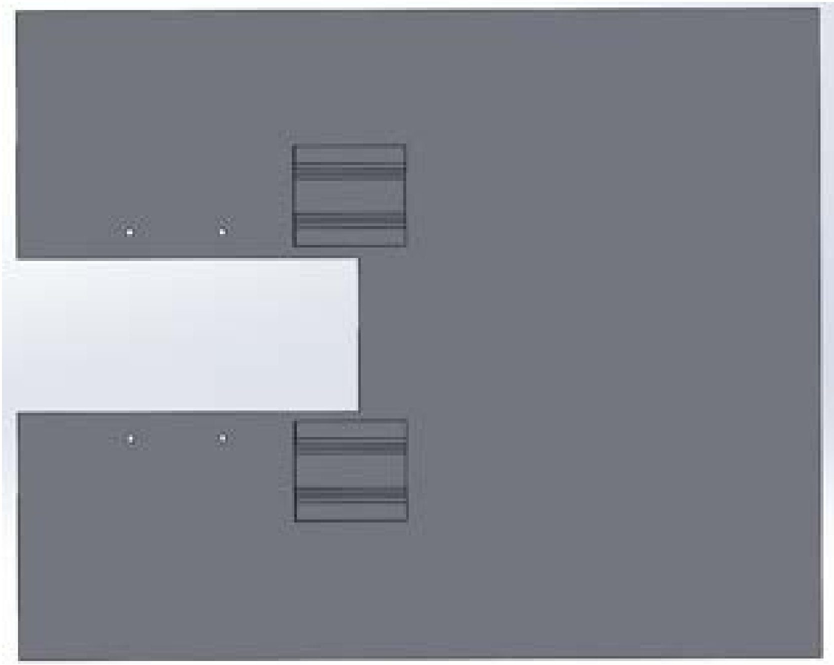


Figure 16: Adding linear slides to assembly

6. Using eight M4 screws, attach two linear slides to the bottom of the phantom bed as illustrated in figure 16.

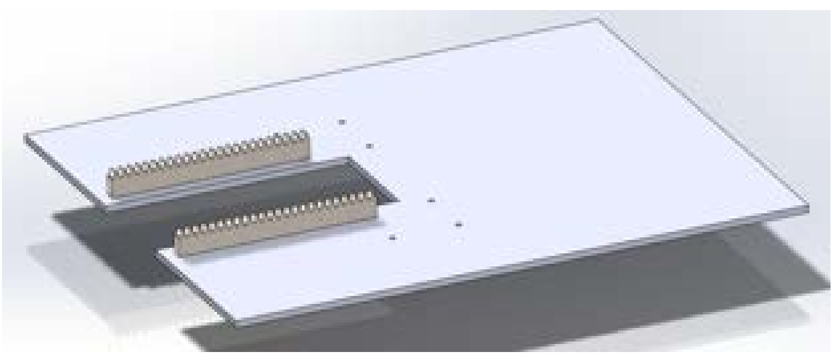


Figure 17: Adding rails to phantom bed

7. Using four M4 screws (two per rail) attach rails to the phantom bed as illustrated in figure 17.

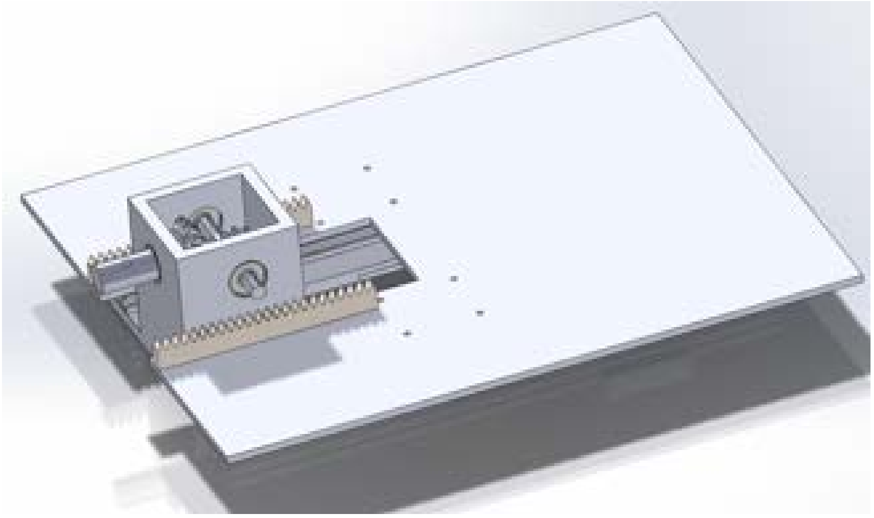


Figure 18: Adding phantom bed to gearbox

8. Slide the linear slides on the bottom of the phantom bed on top of the linear rails attached to the gearbox as illustrated in figure 18.

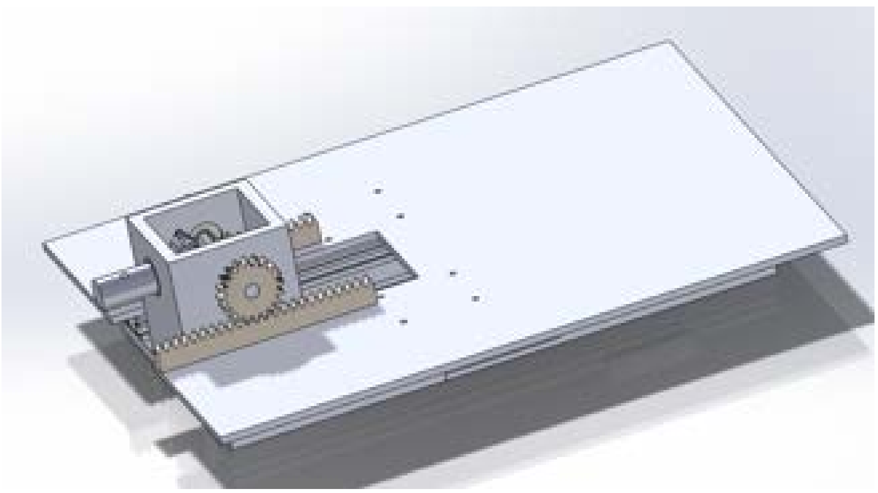


Figure 19: Adding pinion gears to assembly

9. Slide pinion gears onto both sides of the crosspin as shown in figure 19.
10. Using two M4 screws, anchor pinion gears to crosspin.

Driveshaft

1. Cut a 10’ long ¾” pvc pipe into half. Only one of the 5’ long pieces will be used in the full prototype assembly.
2. In the TEAM Lab, using a drill press, drill a 10mm hole 8mm from one end of the pipe.
3. Using a drill press, drill a 5mm 10mm from the other end of the pipe.

Full Prototype Assembly

Figure 20: Attaching driveshaft to gearbox

1. Connect one side of the 5’ driveshaft to the gearbox to driveshaft adapter via a M5 screw.

Figure 21: Attaching driveshaft to Motor assembly

2. Connect the other side of the 5’ driveshaft to motor assembly via a M10 screw and nut as illustrated in figure 21.

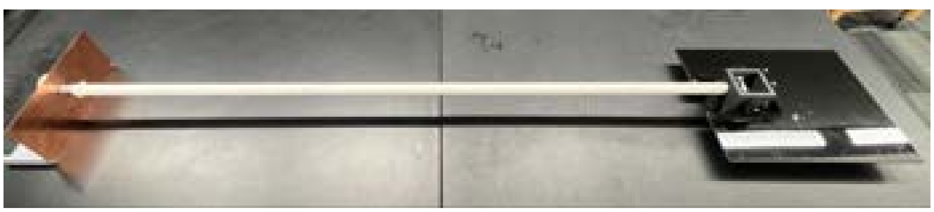


Figure 22: Full prototype assembly

3. Full prototype has been completed.

Conclusions/action items:

2023/11/17 Motor Temperature Protocol

Amber Schneider - Nov 17, 2023, 1:05 PM CST

Title: Motor Temperature Protocol

Date: 11/17/2023

Content by: Amber Schneider

Present:

Goals: outline the protocol for measuring the temperature of the motor under 2 conditions

Content:

Motor Temperature Test

Description:

This test is performed to determine safety values of the motor relating to temperature. It also explores the effectiveness of using a copper plate as a heat sink.

Materials:

1. Ultrasonic Motor
2. Microcontroller & Wires
3. Copper Sheet
4. Infrared Thermometer
    a. *Alternate: Thermistor*
5. Stopwatch

Procedure:

1. Connect the motor to the microcontroller and plug into power.
2. Connect the microcontroller to a laptop with the required files.
3. Ensure that the latest version of the active program is uploaded to the motor.
    a. The latest main.cpp can be downloaded from Lab Archives.
    b. The terminal should output: "Enter 0 to Exit, Enter 1 for incrementWrite() hardcoded demo, Enter 2 for sinusoidal demo"
4. Begin control trial by entering 2 into the terminal to begin the sinusoidal demo.
5. Start the stopwatch.
6. Measure the temperature of the motor with the infrared thermometer pointed at the purple section of the motor.
7. Record the initial temperature of the motor in a spreadsheet at t=0.
8. Repeat temperature measurement every 15s. Record time and temperature.
    a. *Alternate: If using a thermistor, measure the temperature continuously with respect to time.*
9. Stop measurements after 5 minutes.
10. For the experimental trial, fix the copper plate to the bottom of the motor. Ensure positioning so heat can be dissipated from the plate.
11. Repeat steps 7-9 with this experimental setup.

12. Repeat control and experimental trials at least three times to get an average of the data.
13. Plot data for each trial using excel or another computer program.
14. Analyze results.

Conclusions/action items:

This test is performed to determine safety values of the motor relating to temperature. It also explores the effectiveness of using a copper plate as a heat sink. Next steps include performing this test.

2023/11/17 Motor Encoder Protocol

Amber Schneider - Nov 28, 2023, 6:31 PM CST

Title: Motor Encoder Protocol

Date: 11/17/2023

Content by: Amber Schneider

Present:

Goals: test the accuracy of the number of revolutions counted by the motor encoder

Content:

Motor Encoder Test

Description:

This test is performed to determine if the number of revolutions counted by the motor encoder is accurate.

Materials:

1. Ultrasonic Motor
2. Microcontroller & Wires
3. Post-It flag
4. Stopwatch

Procedure:

1. Connect the motor to the microcontroller and plug into power.
2. Connect the microcontroller to a laptop with the required files.
3. Ensure that the latest version of the active program is uploaded to the motor.
    a. The latest main.cpp can be downloaded from Lab Archives.
4. Place a thin post-it flag on the motor shaft to mark an initial position.
5. Run the function “revolutionsCounter()” by pressing 4 and start a stopwatch at the same time.
    a. This program will rotate the motor at 60 RPM until encoder counts 60 revolutions.
    b. This program is expected to run for 60 seconds.
6. While the program is running, visually count the actual number of revolutions.
7. Compare actual number of revolutions against expected value. Make a note if the motor does not end in the same orientation as it started.
8. Repeat 3-5 times.

Conclusions/action items:

This test is performed to determine if the number of revolutions counted by the motor encoder is accurate. Next steps include performing this test and analyzing the results.

Amber Schneider - Nov 28, 2023, 6:36 PM CST

Download

main.cpp (7.49 kB)

2023/12/3 Motor RPM Test Protocol

Amber Schneider - Dec 04, 2023, 1:16 PM CST

Title: Motor RPM Test

Date: 12/4/2023

Content by: Amber

Present:

Goals: Test the accuracy of the motors rpm and speed control

Content:

Motor RPM Test

Description:

This test is performed to determine if the rotations per minute of the motor is accurate. At programmed speeds the prototype will be assessed to how accurate the physical speed is compared to the expected speed. At least 5 trials will be conducted for each set speed. The load will be constant throughout the trials.

Materials:

1. Ultrasonic Motor
2. Microcontroller & Wires
3. Post-It flag
4. Camera
5. Kinovea software

Procedure:

1. Connect the motor to the microcontroller and plug into power.
2. Connect the microcontroller to a laptop with the required files.
3. Ensure that the latest version of the active program is uploaded to the motor.
    a. The latest main.cpp can be downloaded from Lab Archives.
4. Place a thin post-it flag on the motor shaft to mark an initial position.
5. Set-up camera in full view of the platform and begin recording a video.
6. Run the function “motorRPMTest()” by pressing 5.
    a. This program will rotate the motor at 20 RPM until the encoder counts 1 revolution.
7. Once complete, stop recording the video.
8. Compare the time to complete the rotation to the expected time.
9. Repeat steps 4-8 until 5 or more trials are completed.
10. Repeat the procedure for a speed of 40 RPM and 60 RPM.

Conclusions/action items:

This test is performed to determine if the rotations per minute of the motor is accurate. At programmed speeds the prototype will be assessed to how accurate the physical speed is compared to the expected speed. At least 5 trials will be conducted for each set speed. The load will be constant throughout the trials.

2023/12/3 Platform Sinusoidal Motion Test

Amber Schneider - Dec 11, 2023, 7:49 PM CST

Title: Platform Sinusoidal Motion Test

Date: 12/10/2023

Content by: Amber Schneider

Present:

Goals: define the testing procedure for the sinusoidal motion test

Content:

Platform Sinusoidal Motion Test

Description:

This test is performed to determine if the platform is moving at the expected displacement of the sine wave. Multiple trials will be conducted at different weights. The motor velocity will be constant throughout trials.

Materials:

1. Fully assembled prototype
2. Bright marker
3. Camera
4. Kinovea software

Procedure:

1. Assemble complete prototype.
2. Connect the motor to the microcontroller and plug into power.
3. Connect the microcontroller to a laptop with the required files.
4. Ensure that the latest version of the active program is uploaded to the motor.
    a. The latest main.cpp can be downloaded from Lab Archives.
5. Place a bright marker on the platform to mark the initial position.
6. Set-up camera in full view of the platform and begin recording a video from the top view.
7. Run the function “sinusoidalSpeedVariation()” by pressing 2.
    a. This program will set the velocity of the motor to a sine wave with amplitude of 10 RPM, frequency of 8/60 Hz, and offset of 0. It will run for 60 seconds.
8. Once complete, stop recording the video.
9. Upload the video to Kinovea. Calibrate by drawing a line of known length on the video.
10. Place a tracking marker on the bright dot in the video. Track the displacement throughout the entire time the platform is moving.
11. Export the data to excel to perform statistical analysis.
12. Repeat steps 5-11 with different weights on the platform, ranging from 0-4 kg.

Conclusions/action items:

This test is performed to determine if the platform is moving at the expected displacement of the sine wave. Multiple trials will be conducted at different weights. The motor velocity will be constant throughout trials.

2023/11/28 Motor Encoder Test

Amber Schneider - Dec 10, 2023, 2:53 PM CST

Title: Motor Encoder Test

Date: 11/28/23

Content by: Kendra

Present: Kendra and Amber

Goals: Record the data that was collected during the motor encoder test.

Content:

the data taken during 5 trials of the "motor encoder test"

trial number	counted rotations (code output)	counted rotations (visually)
1	60	60
2	60	60
3	60	60
4	60	60
5	60	60
Average:	60	60
Difference:	0	

Conclusions/action items:

The motor is spinning the same amount of revolutions as the encoder is counter.

2023/11/28 Preliminary Motor RPM Test

Amber Schneider - Dec 10, 2023, 2:52 PM CST

Title: Preliminary Motor RPM Test

Date: 11/28/23

Content by: Kendra

Present: Kendra and Amber

Goals: time the duration it takes for the motor to spin 60 revolutions at 60 RPM

Content:

trial number	Revolutions (encoder)	Duration (sec)
1	60	53.39
2	60	52.7
3	60	53.6
4	60	52.9
5	60	53.64
Average:	60	53.25
Difference:	6.754	

Conclusions/action items:

The duration is shorter than expected (60 seconds). A more in depth test is needed to determine what the cause of this error is.

2023/12/4 Motor RPM Test

Amber Schneider - Dec 10, 2023, 2:45 PM CST

Title: Motor RPM Test

Date: 12/4/2023

Content by: Amber Schneider

Present: Amber

Goals: collect data of expected RPM vs programmed RPM to determine amount of error in the motor code

Content:

This test was performed as described in the Motor RPM protocol.

Trial #	Expected RPM	Start Time (s)	End Time (s)	Duration for 1 Revolution (sec)	Actual RPM			
1	20	0.05	3.6	3.55	16.90		Avg RPM	15.63
2	20	0.15	5.22	5.07	11.83		STD	2.206758439
3	20	0.05	3.83	3.78	15.87		% Error	21.82744506
4	20	0.05	3.76	3.71	16.17			
5	20	0.05	3.5	3.45	17.39			
6	40	0.05	2.45	2.4	25.00		Avg RPM	26.66
7	40	0.05	2.33	2.28	26.32		STD	1.226196632
8	40	0.05	2.33	2.28	26.32		% Error	33.33823559
9	40	0.05	2.23	2.18	27.52			
10	40	0.05	2.18	2.13	28.17			
11	60	0.7	1.62	0.92	65.22		Avg RPM	50.69
12	60	0.98	1.9	0.92	65.22		STD	13.78406661
13	60	0.1	1.55	1.45	41.38		% Error	15.50970077
14	60	0.08	1.77	1.69	35.50			
15	60	0.08	1.38	1.3	46.15			

Conclusions/action items:

The average RPM during each test is lower than expected. STD increases as RPM is increased. The team will need to interpret these results, identify the cause, and come up with a solution to this error.

2023/12/6 Platform Sinusoidal Motion Test

Amber Schneider - Dec 10, 2023, 2:49 PM CST

Title: Platform Sinusoidal Motion Test

Date: 12/6/2023

Content by: Amber Schneider

Present: Amber, Kendra

Goals: perform Platform Sinusoidal Motion Test

Content:

This test was performed by following the Platform Sinusoidal Motion Protocol. 2 trials were conducted-- the first with 0kg of added weight and the second with 4kg of added weight. The excel files are attached below. They contain the tracking results from the test along with statistical analysis.

Conclusions/action items:

Time between Peaks (T = 7.50 s)

0kg: 7.50 ± 0.4 s | 3.87% error

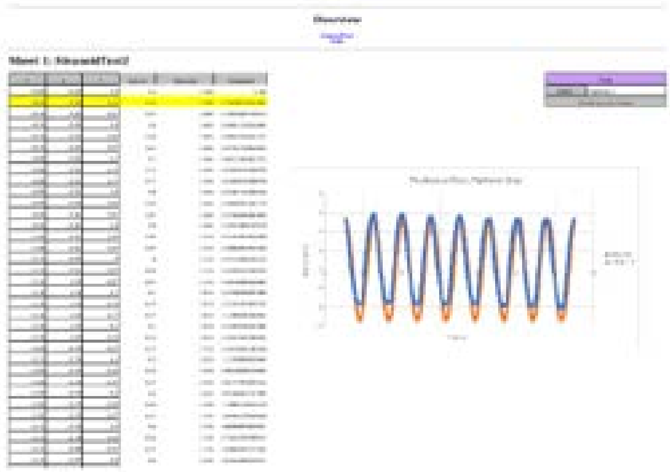
+4kg: 7.50 ± 0.7 s | 7.30% error

Peak to Peak Amplitude (AP-P = 5.41 cm/s)

0kg: 4.619 ± 0.07 cm | 14.63% error

+4kg: 4.685 ± 0.05 cm | 13.39% error

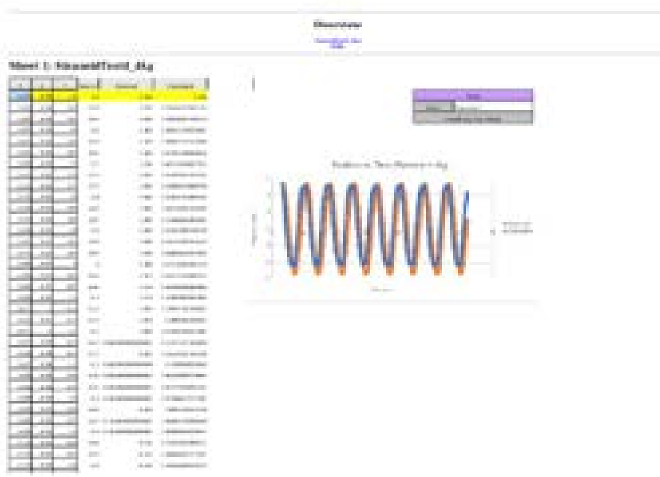
Amber Schneider - Dec 10, 2023, 2:49 PM CST



Download

SinusoidTest1.xlsx (181 kB)

Amber Schneider - Dec 10, 2023, 2:50 PM CST



Download

SinusoidTest4_4kg.xlsx (184 kB)

2023/13/09 Magnetic Resonance Imaging

Amber Schneider - Sep 13, 2023, 9:07 PM CDT

Title: Magnetic Resonance Imaging (MRI)

Date: 9/13/2023

Content by: Amber Schneider

Present:

Goals: understand what an MRI is, how it works, and what it is used for

Content:

“Magnetic Resonance Imaging (MRI),” National Institute of Biomedical Imaging and Bioengineering, https://www.nibib.nih.gov/science-education/science-topics/magnetic-resonance-imaging-mri#:~:text=MRIs%20employ%20powerful%20magnets%20which,pull%20of%20the%20magnetic%20field. (accessed Sep. 13, 2023).

What is MRI?

- non-invasive imaging technology
- produces 3D detailed anatomical images
- used for disease detection, diagnosis, and treatment monitoring
- technology that **excites** and **detects** the change in the direction of the **rotational axis** of **protons** found in the **water** that makes up **living tissues**

How does MRI work?

- Use powerful magnets to produce a strong magnetic field that forces protons in the body to align with that field
- A radiofrequency current is pulsed through the patient
- Protons are stimulated, and spin out of equilibrium, straining against the pull of the magnetic field
- Radiofrequency field is turned off, MRI sensors detect the energy released as the protons realign with the magnetic field
- Time it takes for the protons to realign with the magnetic field, as well as the amount of energy released, changes depending on the environment and the chemical nature of the molecules
- Physicians are able to tell the difference between various types of tissues based on these magnetic properties

Obtaining an Image

- patient is paced inside large magnet
- **must remain very still** so the images do not get blurred
- Contrast agents (often containing the element Gadolinium) may be given to a patient intravenously before or during the MRI
    - Increase the speed at which protons realign with the magnetic field
    - The faster the protons realign, the brighter the image

What is MRI used for?

- image non-bony parts or soft tissues of the body
    - The brain, spinal cord and nerves, as well as muscles, ligaments, and tendons are seen much more clearly with MRI than with regular x-rays and CT

    - MRI is often used to image knee and shoulder injuries
- In the brain, MRI can differentiate between white matter and grey matter and can also be used to diagnose aneurysms and tumors
- imaging modality of choice when frequent imaging is required for diagnosis or therapy (no radiation)
- MRI is more expensive than x-ray imaging or CT scanning

Risks

- strong magnetic field that extends beyond the machine
- People with implants (particularly those containing iron)
- Noise
- Nerve Stimulation
- Contrast agents
- Pregnancy
- Claustrophobia

Conclusions/action items:

An MRI is a powerful diagnostic tool that allows physicians to take images of tissue in the body. It works by using magnets and applying a current that moves the Hydrogen atoms found in tissue, then once the current is stopped, the return of the Hydrogen atoms to align with the magnetic field is recorded and made into an image. It was mentioned that must remain very still during an MRI, which is the main point our project is trying to address.

2023/13/09 Quantitative Brain MRI

Amber Schneider - Sep 13, 2023, 9:17 PM CDT

Title: Quantitative Brain MRI

Date: 9/13/2023

Content by: Amber Schneider

Present: understand the "quantitative" aspect of MRI

Goals:

Content:

Pierpaoli, Carlo. “Quantitative brain MRI.” Topics in magnetic resonance imaging : TMRI vol. 21,2 (2010): 63. doi:10.1097/RMR.0b013e31821e56f8

- Quantitative MRI refers to measuring numeric values of signal intensities alongside visual inspection in imaging studies
- A stricter definition of quantitative MRI involves obtaining maps of physical or chemical variables in physical units for comparison between tissues and subjects
- Most clinical MRI acquisitions traditionally aren't quantitative, relying on weighted images with contrast influenced by various factors
- Conventional MRI excels in diagnosing gross abnormalities or focal differences in signal intensities but lacks sensitivity to subtle global brain changes
- Quantitative MRI can enhance sensitivity by comparing measurements to normative values from healthy populations and tracking disease progression or remission
- Conventional MRI lacks biological specificity as different factors can produce similar image contrast changes
- Quantification plays a crucial role in developing imaging biomarkers
- Despite the benefits of quantitative MRI, clinical neuroradiology still relies primarily on qualitative techniques
- Experts in neuroimaging discuss quantification issues and obstacles in various MRI techniques in this issue:
    - Perfusion MRI using arterial spin labeling
    - Perfusion MRI using dynamic-susceptibility contrast
    - Diffusion MRI
    - MRI proton relaxometry
    - Proton magnetic resonance spectroscopy and spectroscopic imaging

Conclusions/action items:

An MRI study is quantitative when there are maps of meaningful physical or chemical variables that can be measured in physical units and compared between tissue regions and among subjects. Most clinical MRI acquisitions are not quantitative, so there may be limited background knowledge available for our project.

2023/09/20 Respiratory motion estimation of the liver with abdominal motion as a surrogate

Title: Respiratory motion estimation of the liver with abdominal motion as a surrogate

Date: 9/20/2023

Content by: Amber Schneider

Present:

Goals: understand how respiratory motion alters MRI

Content:

S. Fahmi, F. F. J. Simonis, and M. Abayazid, “Respiratory motion estimation of the liver with ... - Wiley Online Library,” Respiratory motion estimation of the liver with abdominal motion as a surrogate, https://onlinelibrary.wiley.com/doi/10.1002/rcs.1940 (accessed Sep. 20, 2023).

Introduction

- Medical imaging modalities (computed tomography (CT), ultrasound (US), magnetic resonance imaging (MRI), etc.) are widely used during diagnosis and treatment of liver cancer
- high-quality and real-time medical images can significantly improve the overall diagnosis and treatment of cancer patients
- MRI offers high image quality (contrast and spatial resolution) at a low update rate
- For liver interventions, the soft tissue contrast in MRI makes it the preferable modality
- The most common cause of inaccurate targeting is internal organ motion
    - One of the main causes of internal organ motion is **respiration**
- Respiratory-induced motion (RIM) mainly affects the organs in the abdominal and thoracic regions (such as lungs, liver, diaphragm, etc.)
- if RIM is not handled together with slow imaging modalities, locating the exact lesion motion will be uncertain, which implies inaccurate targeting of the inserted needle during percutaneous interventions
- A common solution to RIM is breath-holding, which requires the patient to hold their breath for approximately 20 seconds
    - **Main disadvantages** of breath-holding are an increase in the intervention time, inconsistent lesion location between breath holds and that patients might feel uncomfortable during breath holds or cannot hold their breath for sufficient time
- An alternative solution to deal with RIM is respiratory motion estimation (RME)
- RME estimates the actual internal motion of interest by measuring external signals that do not directly measure the actual internal motion of interest but have a strong correlation with it and can be easily measured
- RME depends on deriving a motion model that mathematically describes the relation between the motion data and surrogate data
- RME consists of two phases: a training phase during which the motion and surrogate data are fed to a fitting method to train the motion model offline, and a prediction phase in which the surrogate data are fed to the motion model to generate motion estimates

Details are in the caption following the image

Figure 1. Overview of RME

- RME can also be used to minimize motion-induced artifacts by adjusting the reconstruction of the acquired images

Discussion

- The acquired data were not affected by other organ-induced motion such as the heart
- The liver SI motion ranged between 10.0 mm and 21.3 mm, which is consistent with previous studies on the liver

Conclusion

- As illustrated in the results, the differences between the 3 regression models were not significant
- Using a more complex regression algorithm would not improve the estimation accuracy significantly

Conclusions/action items:

RIM causes uncertainties in imaging that can cause inaccurate targeting during intervention, causing a risk to the patient. Typically, one would hold their breath to mitigate these motions, however, that is not possible in every scenario for a multitude of reasons. This study proposes using a respiratory motion estimation, where the motion is estimated by measuring external signals. Using machine learning, the method was validated and the results showed that the motion of the liver could be estimated.

2023/09/20 An MRI-Compatible Platform for One-Dimensional Motion Management Studies in MRI

Amber Schneider - Sep 20, 2023, 6:58 PM CDT

Title: An MRI-Compatible Platform for One-Dimensional Motion Management Studies in MRI

Date: 9/20/2023

Content by: Amber Schneider

Present:

Goals: define the competing design, list pros and cons

Content:

J. Nofiele et al., "An MRI-compatible platform for one-dimensional motion management studies in MRI," Magnetic resonance in medicine, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6342555/ (accessed Sep. 20, 2023).

Abstract

Abdominal MRI remains challenging because of respiratory motion. Motion compensation strategies are difficult to compare clinically because of the variability across human subjects. The goal of this study was to evaluate a programmable system for one-dimensional motion management MRI research.

Introduction

- Respiratory motion is the main challenge in MRI acquisitions of the abdomen due to motion of the intra-abdominal organs and the abdominal walls
- causes image artifacts such as blurring, aliasing, and ghosting
- lead to reduced quality of MRI images, compromising its diagnostic performance
- breath-hold acquisitions are routinely used in clinical practice to achieve motion-free MRI of the torso
    - breath-hold approaches may be incompatible with long MRI acquisitions or even short MRI acquisitions in patients with limited breathhold capability
- motion artifacts may have an effect on quantitative MRI measures
    - longitudinal relaxation time T1
    - transverse relaxation time T2
    - effective transverse relaxation rate T2*
    - apparent diffusion coefficient
- **A motion platform that can reproducibly replicate the motion of abdominal organs in the MRI environment, combined with a variety of phantoms, would provide the means for developing and testing different diagnostic and therapeutic MRI strategies for specific clinical scenarios and needs.**
- Previous studies have used
    - patient table of the magnet
    - pneumatic systems
    - hydraulic systems
    - electromagnetic systems
    - piezoceramic actuators

MRI-Compatible Motion Platform

- two parts: a motorized linear stage located inside the bore of the MRI, and driving electronics located at the operator suite
    - motorized stage was constructed using three nonmagnetic linear bearing slides and was driven with two nonmagnetic piezoceramic motors

- optical encoder was used to provide position information
- motor amplifier, power supply, connector box
- Customwritten software in LabVIEW
  - FREE from authors
  - The software was capable of displaying and recording real-time position of the stage during imaging

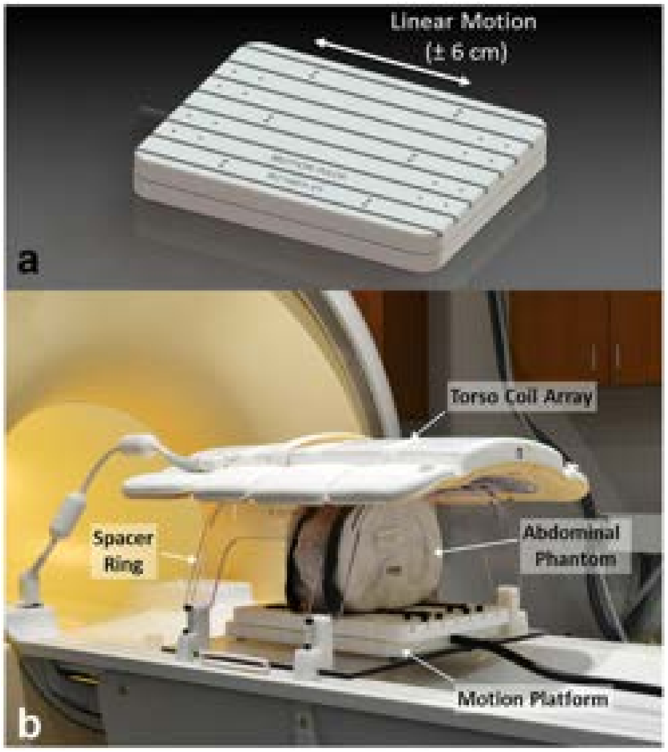


Figure 1. MRI Platform Experimental Setup

- Pro: ability to program custom motion trajectories using the software interface associated with the system
- Con: restriction of motion to one linear dimension

Conclusions/action items:

This experimental setup is similar to what our project is trying to achieve. It is larger than what we are planning to fabricate. It only moves in 1 direction, which the authors believe is a con. We should aim to have similar features in our final product, such as the ability to control movement and record data using software.

2023/10/02 Torque Calculations

Amber Schneider - Oct 04, 2023, 8:57 AM CDT

Title: Torque Calculations

Date: 10/2/2023

Content by: Amber Schneider

Present:

Goals: brainstorm how to compare required torque of each mechanism

Content:

$T = Torque\ required\ from\ motor\ (Nm)$
$L = Screw\ lead\ \left(\frac{mm}{rev}\right)$
$e = Lead\ screw\ efficiency$

$$T = F * \frac{L\ /\ 1000}{2\pi e}$$

Tangential force on the rack: vertical application

In a vertical application, the load moves in the direction of the guide system, so the force due to the moved mass is not affected by the coefficient of friction of the guide rails.

$$F_r = m \cdot g + m \cdot a + F_e$$

Torque on the pinion

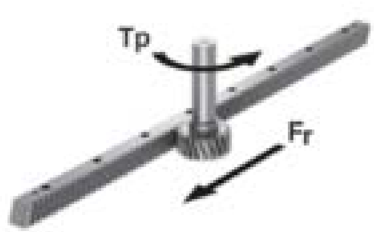
The torque on the pinion is simply the tangential force (force on the rack) multiplied by the pinion radius.

$$T_p = F_r \cdot r_p$$

T_p = torque on pinion (Nm, ft-lb)

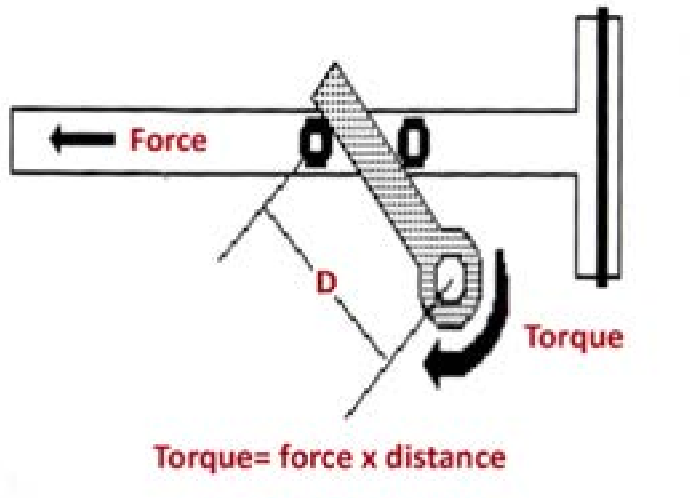
r_p = pinion radius (m, ft)

Remember to divide the pinion diameter by 2 to get the radius, and by 1000 to convert from mm to m (or by 12 to convert from inches to feet).



The amount of torque a scotch-yoke actuator will produce is based on all of the factors of the torque formula (T=p x A x d), but for a given piston size and air pressure it is the length of the yoke (d) that is the main determining factor.

The scotch-y
linear



Conclusions/action items:

Outlined above are the 3 ways to calculate the torque of each design idea. This will be useful in future calculations to determine if the design meets the requirements of the PDS.

2023/10/04 Lead Screw Information

Amber Schneider - Oct 04, 2023, 8:59 AM CDT

Title: Lead Screw Information

Date: 10/4/2023

Content by: Amber Schneider

Present:

Goals: characterize lead screw mechanism

Content:

"Why lead screws best fit linear motion applications," Thomson Linear, https://www.thomsonlinear.com/downloads/articles/Why_Lead_Screws_Best_Fit_Linear_Motion_Applications_taen.pdf (accessed Oct. 4, 2023).

- Load Capacity: Less than 100 pounds (300 max)
- Efficiency: 20% to 80%
  - Depends on helix angle
    - Higher angle = Higher efficiency
    - This is because the number of times the screw must rotate to achieve the same linear displacement is reduced on a high helix screw.
    - A disadvantage of a high helix angle is that more torque is required to turn the screw
  - Backdriving requires lead ≥ ⅓ screw diameter
    - Ideally lead = screw diameter
    - It's important to note that when the efficiency of a lead screw exceeds 50%, the lead screw becomes back-drivable, which means it can be driven backwards by the load.
- Speed:
  - High level of accuracy → lead screw with low helix angle
  - Max RPM limited by critical speed of the screw (speed at which resonance occurs)
- Duty Cycle: 50% under rated (plastic)
  - High load and high rpm relative to a given thread size and nut design will result in over heating and failure.
- Materials: Plastic nuts typically travel on stainless steel screws
  - *Austenitic stainless steel is MRI compatible*

Conclusions/action items:

Lead screws convert rotational motion to linear motion using a helix angle of a thread driven by a motor. The higher the helix angle, the greater efficiency the mechanism produces. Typically this setup is used for light loads less than 100 pounds (45kg). A drawback is that the friction wear is non-linear, depending on the material's coefficient of friction and pressure-velocity factor.

2023/10/04 Scotch Yoke Information

Amber Schneider - Oct 04, 2023, 9:05 AM CDT

Title: Scotch Yoke Information

Date: 10/4/2023

Content by: Amber Schneider

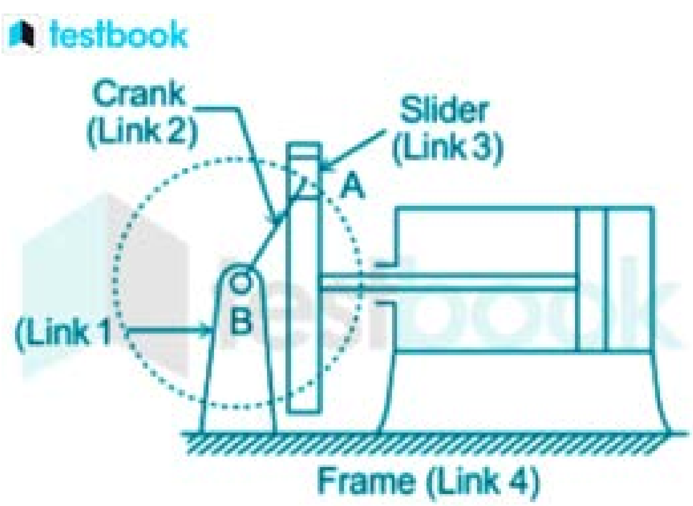
Present:

Goals: characterize scotch yoke mechanism

Content:

"Scotch Yoke Mechanism: Working, Advantages and Applications.," Testbook. Accessed: Oct. 04, 2023. [Online]. Available: https://testbook.com/mechanical-engineering/scotch-yoke-mechanism-application

- Consists of a slotted yoke and a pin-mounted disc to convert rotational motion to reciprocating linear motion
  - At a given constant rotational speed, the piston's motion has the form of a pure sine wave over time
- Variable torque
  - Smaller cylinder capacity and higher torque output
- Due to high contact pressures and moving friction, the yoke's slot wears out quickly



Advantages

- Smaller cylinder capacity and higher torque output.
- Easy to assemble, operate and build.
- Smoother operation due to fewer moving components.
- Engine efficiency is increased by a higher proportion of time spent at the top dead centre.
- It can be easily automated.

Disadvantages

- Due to high contact pressures and moving friction, the yoke's slot wears out quickly.
- A constant rotation speed is produced over time by the piston action, which is a pure sine wave. Until that time, the motion is non-linear.
- Reduced blow-down time for two-stroke engines due to a lower proportion of time spent at the bottom dead centre.

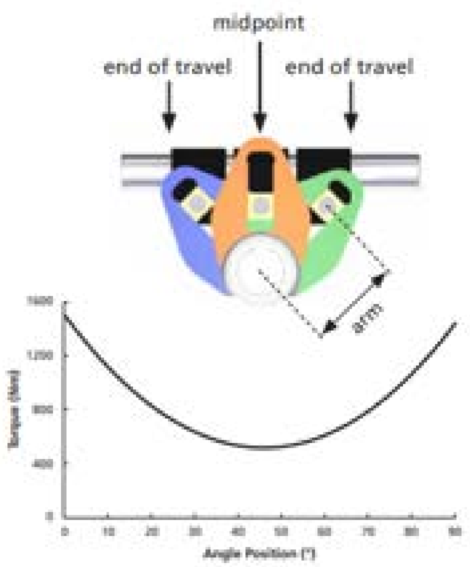
- For limbs to reciprocate properly, guides are required.

Conclusions/action items:

A scotch yoke mechanism produced reciprocating linear motion from initial rotational motion. A constant rotational speed creates a sine wave motion, however, until then it is nonlinear. It can produce variable torque depending on the cylinder radius. A drawback of this design is that the slot wears out quickly due to high contact pressures and moving friction.

Amber Schneider - Oct 07, 2023, 6:04 PM CDT

Rotork, “Fluid Power Actuators explained,” Rotork Fluid Systems, https://www.rotork.com/uploads/documents-versions/24733/1/pub010-024-00_0516.pdf (accessed Oct. 7, 2023).



Scotch Yoke Torque Profile

- Dimension of arm is greatest at both ends of travel
  - Highest Torque
- Dimension is shortest at the midpoint
  - Lowest Torque
- U-shaped output torque characteristic
- To generate more torque, piston surface and/or movement arm must be **increased**

2023/10/04 Rack & Pinion Information

Amber Schneider - Oct 04, 2023, 9:12 AM CDT

Title: Rack and Pinion Information

Date: 10/4/2023

Content by: Amber Schneider

Present:

Goals: characterize rack and pinion mechanism

Content:

M. Anselmo, “How do Rack-and-Pinion Drives Stack up Against Other Linear Motion Systems?,” Machine Design. Accessed: Oct. 04, 2023. [Online]. Available: https://www.machinedesign.com/mechanical-motion-systems/article/21831764/how-do-rackandpinion-drives-stack-up-against-other-linear-motion-systems

- Rotational motion (rack) transferred to linear motion (pinion)
- High efficiency transfer
- Increasing gear teeth density
- Increased precision
- Requires constant motor directional change
- Causes stress on motor
- Unlimited travel distances
- **Efficiencies up to 98.5%**
- Design flexibility for getting the performance and control that matches their application’s needs
- Putting the pinion and rack teeth too far apart causes backlash, which lowers precision

- Misaligned mounting can damage the gearbox bearings, which leads to higher motor currents, noise, and even failures

Conclusions/action items:

A rack and pinion translates rotational motion into linear motion. It offers very high efficiency and also low backlash. Its precision is dependent on the positioning of the teeth. Future work involves investigating helical rack and pinions to see if that is a better fit to our specifications.

2023/10/09 Ultrasonic Motors

Amber Schneider - Oct 09, 2023, 4:58 PM CDT

Title: Ultrasonic Motors

Date: 10/9/2023

Content by: Amber Schneider

Present:

Goals: understand the technology behind the ultrasonic motor

Content:

T. Agarwal, “Piezoelectric ultrasonic motor technology and applications,” ElProCus, https://www.elprocus.com/piezoelectric-ultrasonic-motor-technology/ (accessed Oct. 9, 2023). Ultrasonic motors are not frictionless like voice coils or linear motors

Piezoelectric Sensor

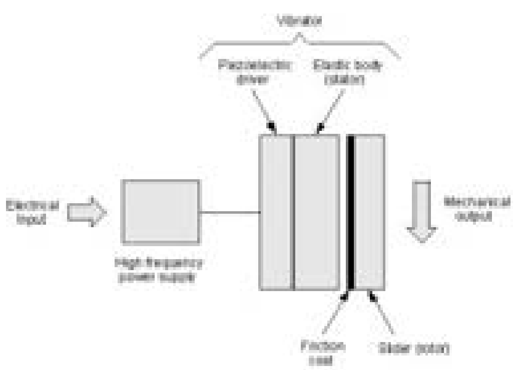
- Changes in physical quantities (strain, force, stress, acceleration) are measured by converting into electrical energy
- Devices/ sensors that are used are **piezoelectric** sensors
- Process is termed as piezoelectric effect

Ultrasonic Sensor

- Transducers that generate high frequency (around 20 kHz to 10 MHz sound waves) and attribute the target by reading the time interval between receiving the echo after sending the signal
- Ultrasonic sensors can be used for obstacle detection

Piezoelectric Ultrasonic Motor Technology

- Electric energy is converted into motion
- Classified by Type
    - **Rotary**
    - Linear



How it Works

- Vibration is induced into the stator of the motor
- Conveys the motion to the rotor and modulates frictional forces
- Amplification and (micro) deformations of active material are utilized for generation of the mechanical motion

- Macro-motion of the rotor can be achieved by the rectification of the micro-motion using the frictional interface between the stator and the rotor
- Consists of stator and rotor
- Operation of the USM changes the rotor
- Stator of the USM consists of piezoelectric ceramics for generating vibration, a metal of the stator for amplifying the generated vibration, and a friction material for making contact with the rotor
- When a voltage is applied, a travelling wave is generated on the surface of the stator metal which causes the rotor to rotate
- The rotor is in contact with the stator metal
    - Only at each peak of the travelling wave
    - Causes the elliptical movement
    - Elliptical movement causes the rotor rotates in the direction conversely to the direction of the travelling wave

Advantages

- Small, light
- low speed and high torque (no reduction gears required)
- high holding power
- no electromagnetic material
- no gears, inaudible frequency vibration (operation is quiet)
- accurate speed and position control are possible
- mechanical time constant is less than 1ms
- speed control is stepless

Disadvantages

- high frequency power supply is required
- low durability due to friction reliability
- drooping speed-torque characteristics

Applications: Used in MRI magnetic resonance imaging scanning in medicine.

Conclusions/action items:

This article discusses piezoelectric ultrasonic motors, their components, how they work, pros and cons, and applications. It is important to understand how this technology works since our client provided us with a rotary piezoelectric motor. Future work includes designing the platform to use the advantages of the motor for our benefit. Additionally, the team needs to begin working with the provided motor to see its full range of capabilities.

2023/11/8 QEI Background & Library

Amber Schneider - Nov 08, 2023, 3:47 PM CST

Title: QEI Background & Library

Date: 11/8/2023

Content by: Amber Schneider

Present:

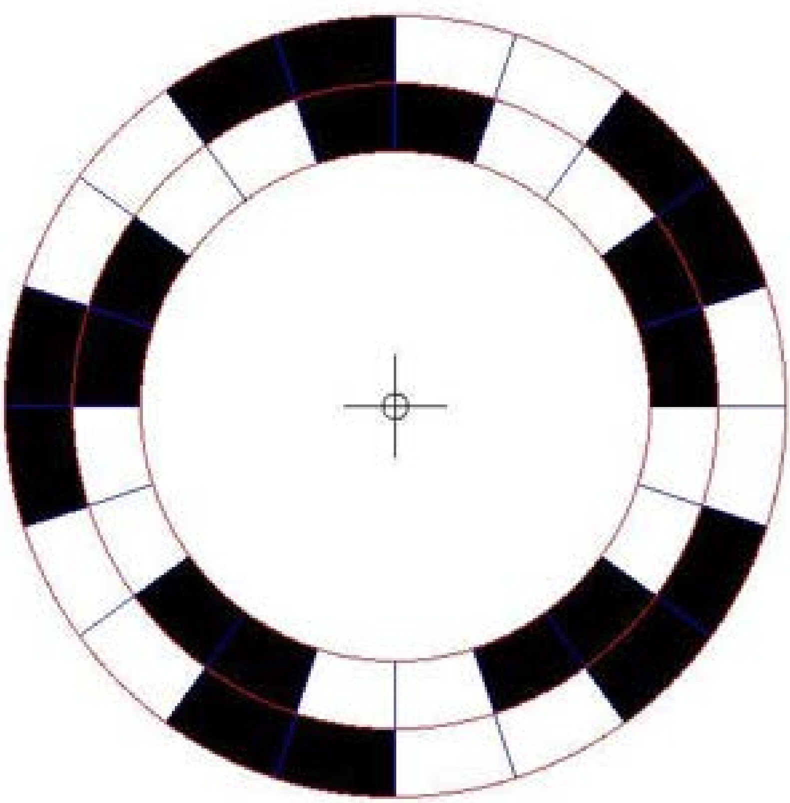
Goals: define Quadrature Encoders, outline QEI library that is used in the main.cpp file

Content:

Website (description): https://os.mbed.com/cookbook/QEI

Library (QEI.cpp & QEI.h): https://os.mbed.com/users/aberk/code/QEI/

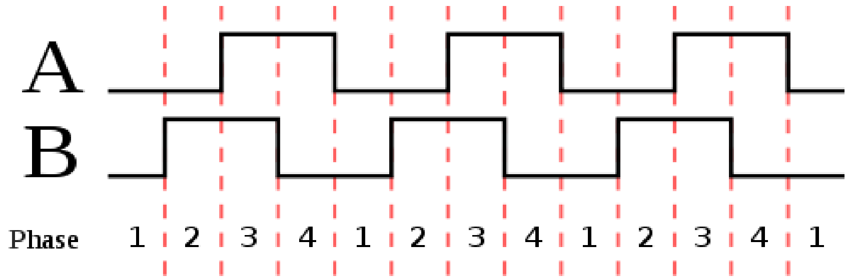
- A rotary encoder converts angular position to an analog or digital code.
- QEI Library describes an **optical quadrature encoder**
- Popular tool for **determining how much a wheel has rotated** and thus **how far something has moved**
- Components:
  - Disc with alternating areas of reflection and non-reflection
  - Emitter and receiver (such as an LED and photodiode) read the resulting optical pattern from the position of the optical encoder



How it Works

- A quadrature encoder consists of a disc with two tracks, containing alternating areas of reflection and non reflection, 90 degrees out of phase

- As it rotates in front of an emitter/receiver pair for each track (which we will call channel A, and channel B), it will produce the following results.



- There are **four distinct states** that can be achieved with this disc
    - Gray codes
- Each time there is a valid state change, the pulse count is incremented, or decremented depending on the direction
- A state change is only valid if only one of the tracks has changed. If both tracks change at the same time the state change is invalid

Clockwise rotations

Phase	Channel A	Channel B
1	0	0
2	0	1
3	1	1
4	1	0

Counter clockwise rotations

Phase	Channel A	Channel B
1	1	0
2	1	1
3	0	1
4	0	0

Software

- The QEI library uses X2 encoding by default, which looks at the state every time a rising or falling edge occurs on channel A.
    - It can also use X4 encoding which looks at the state every time a rising or falling edge occurs on channel A or channel B.
- After each rising or falling edge the pulse count is updated appropriately, depending on the direction of rotation.
- Channel A and channel B are used as InterruptIn pins to ensure as few pulses as possible are missed that might cause invalid state readings or an incorrect count, which could be the case if polling was used.

- An optional index channel is available which is essentially a third track on the disc which has one pulse per revolution. Thus it can keep track of the **number of revolutions of the disc**.
- After creation of a QEI object, any change in the position of the encoder wheel will cause an update of the internal pulse count
- **The library methods can be used to find out what the current pulse count is (which with supporting code can be used to determine absolute position) and reset the pulse and revolution count**
- The current state of the encoder can also be queried, but it is there purely for convenience - most, if not all users will not require this method.
- It should be noted that the internal revolution count is only updated by the index channel. If no index channel is used, it is still easy to work out the current revolution count by **dividing the pulse count by number of pulses per revolution for the disc**, but this must be done in external code.

API

QEI - QEI Class Reference

Import library

Public Member Functions

	QEI (PinName channelA, PinName channelB, PinName index, int pulsesPerRev, Encoding encoding=X2_ENCODING) Constructor.
void	reset (void) Reset the encoder.
int	getCurrentState (void) Read the state of the encoder.
int	getPulses (void) Read the number of pulses recorded by the encoder.
int	getRevolutions (void) Read the number of revolutions recorded by the encoder on the index channel.

Conclusions/action items:

Quadrature encoders can be used to keep track of the number of revolutions of the motor, which can also be used to calculate how far something (such as the stage of our device) has moved. This will be a useful feature to implement into our code, as it will allow us to start our device from the same spot each time we run the code. Furthermore, it will allow us to reset the position. Additionally, it could be used to track how much the stage has moved during a test, which could be useful information for researchers to know.

2023/09/26 Lead Screw Design

Amber Schneider - Sep 26, 2023, 8:51 PM CDT

Title: Lead Screw Design

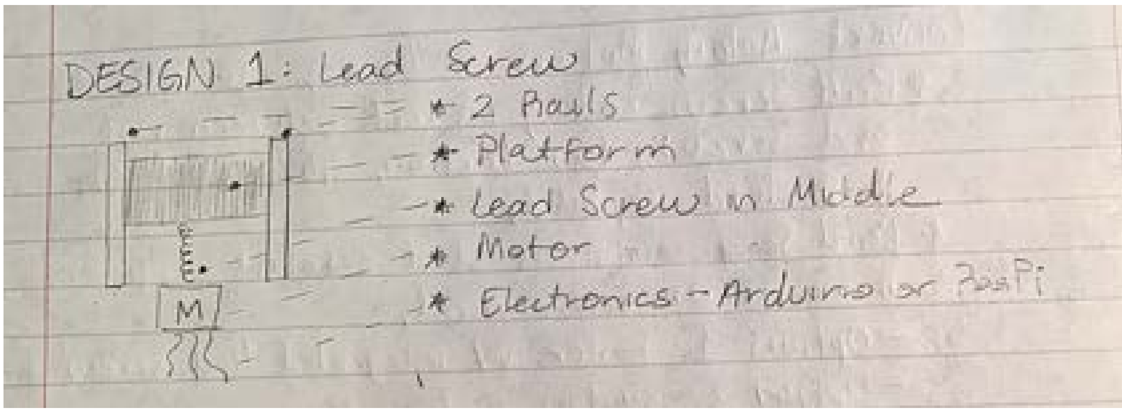
Date: 9/26/2023

Content by: Amber Schneider

Present:

Goals: outline idea for a lead screw design

Content:



[Lead Screws Explained]

Pros:

- Lead screws are cheap and reliable as they only have a few parts
- They require little to no maintenance
- Smooth and quiet operation
- Capable of lifting heavy loads
- Some power screws have self-locking property
- Low pitch screws can give highly precise measurements, which are vital in machine tool applications

Cons:

- In comparison to other mechanical power transmission methods, leadscrews have a high wear rate
- Not suitable for applications with a very high torque demand
- They have relatively poor efficiency

Conclusions/action items:

My first design idea translates the rotary motion of the motor into linear motion using a lead screw. The lead screw would be positioned in the middle of the moving platform. The platform would be guided forward and backward with rails on each side. Variables to consider include load capacity, speed, pressure-velocity factor, and lubrication. Action items include performing calculations using estimated phantom weight to see if the speed and torque needed are reasonable to be preformed by this design.

2023/09/26 Rack and Pinion Design

Amber Schneider - Sep 26, 2023, 9:00 PM CDT

Title: Rack and Pinion Design

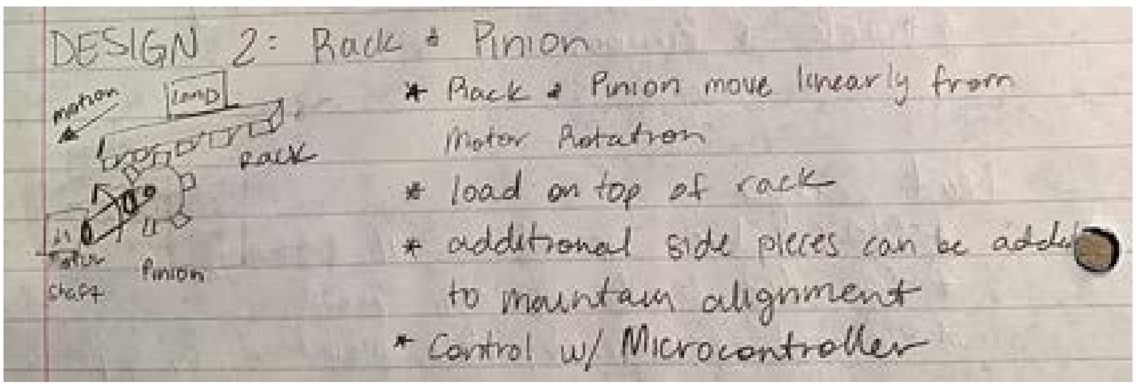
Date: 9/26/2023

Content by: Amber Schneider

Present:

Goals: outline idea for a rack and pinion design

Content:



Rack and Pinion Explained

Conclusions/action items:

My second design idea translates the rotary motion of the motor into linear motion using a rack and pinion. The rack would be positioned in the center and under the moving platform. The platform will extend outside the width of the rack, and will be guided by linear rails on each side. This mechanism is driven by variables such as tooth pitch, size of the pinion, and gear ratio. Action items include performing calculations to see if the speed, torque, and precision needs can be met by this design.

2022/02/17 EMU Account Status & Green Pass

Amber Schneider - Feb 17, 2022, 11:15 PM CST

You have the following permits and upgrades:

Name	Date
Green Permit	01/25/2022
Lab Orientation	09/22/2020
Red Permit	10/14/2021
Laser 1	10/06/2020

Amber Schneider - Mar 06, 2022, 4:13 PM CST

Download

greenPass.pdf (280 kB)

2023/10/19 Initial Motor Meeting

Amber Schneider - Nov 07, 2023, 12:43 PM CST

Title: Initial Motor Meeting

Date: 10/19/2023

Content by: Amber Schneider

Present: Kendra Besser

Goals: get motor code from client working on laptop

Content:

Client provided code to Kendra in an Email:

"Please find the preloaded code attached to this email. In particular, the main.cpp and QEI folder (encoder library) are probably the most interesting.

However, please note that this was sent to me directly by the motor vendor, and I've never tried to load code onto the microcontroller myself and so I may not be much help in that regard. I personally would refer to the pin interface on the motor driver (which I think is described in the manual I gave your team) and use a microcontroller that you're more familiar with to send signals to that interface. Still, hopefully the attached reference implementation can get your team started."

- Downloaded 7-Zip to view inside the .tar file
    - NOT NECESSARY -- can treat like .zip file and unzip into folder
- Files of Interest
    - main.cpp
        - Written in C++
        - Source code file
    - QEI.lib
        - encoder library
        - use in the future to track motor rotation & determine position
- Downloaded Termite (RS232 terminal)
    - Termite is an easy to use and easy to configure RS232 terminal
    - It uses an interface similar to that of "messenger" or "chat" programs, with a large window that contains all received data and an edit line for typing in strings to transmit
    - Highlights of the utility are the ease of installation (possibly with pre-configured settings) using a heuristic search for the appropriate COM port and, as was mentioned, its user-friendliness.

Termite & Main.cpp

1. Open Termite app
2. Initialize the COM Port by pluggin in the ultrasonic motor into the laptop
3. Load program onto microcontroller
    1. *This may already be standard*
4. Demo code will appear. Follow instructions on screen.

Conclusions/action items:

Successfuly ran main.cpp file on Termite. Used terminal to try both demos. Both demos require user to input desired values to control the motor. Future work includes learning how to edit the C++ file.

Amber Schneider - Nov 07, 2023, 12:34 PM CST

Download

KIT_DEV_WLG-75_A00.tar (871 kB)

2023/10/20 Mbed Functionality Meeting

Amber Schneider - Nov 07, 2023, 1:07 PM CST

Title: Mbed Functionality Meeting

Date: 10/20/2023

Content by: Amber Schneider

Present: Kendra Besser

Goals: find a way to edit C++ file, possibly run file on software other than termite

Content:

- Termite does not allow for the user to edit C++ files
- **Mbed Operating System**
  - Using Keil Studio Cloud you can import Mbed OS source code as a library, building your application against the C++ API
  - Alternatively, you can find the Mbed OS source code on Github.
    - **Widely used**
  - Official Examples
    - We maintain code examples that help you to utilize key functionality of Mbed OS
- Mbed Studio
  - Mbed Studio is a free IDE for Mbed OS application and library development, including all the dependencies and tools you need in a single package so that you can create, compile and debug your Mbed programs on the desktop.
  - Downloaded for Windows.
    - Guide from Mbed website
- Created mbed-os-example-blinky
  - Followed Mbed OS Blinky tutorial
  - **SUCCESS**

Conclusions/action items:

Successfully downloaded mbed to edit C++ files and compile them. Used mbed to blink the LED on the microcontroler (while board connected to the motor). Future work includes loading the main.cpp file given by the client into mbed and getting it to run on mbed.

2023/10/25 Getting Motor Files to work on Mbed

Amber Schneider - Nov 07, 2023, 1:23 PM CST

Title: Getting Motor Files to work on Mbed

Date: 10/25/2023

Content by: Amber Schneider

Present: Kendra Besser

Goals: Run files from client on mbed

Content:

Problem: when directly importing the folder from the client into mbed, the OS is outdated (version 2 instead of 5)

Work Around

- Create empty mbed program
- Copy in main.cpp
- Address errors line by line

Errors resolved:

1. No connection to serial monitor
2. Take out lines that require user input
3. Update libraries

Conclusions/action items:

Went through the main.cpp file given by the client in a clean, updated workspace. Worked through resolving errors line-by-line. Involved downloading current versions of libraries from online mbed sites. Relevant files are attached below. Future work includes creating our own function to produce sinusoidal motion of the motor.

Amber Schneider - Nov 07, 2023, 1:24 PM CST

Download

mbed-os.lib (79 B)

Amber Schneider - Nov 07, 2023, 1:24 PM CST

Download

QEI.lib (82 B)

Amber Schneider - Nov 07, 2023, 1:24 PM CST

Download

ttmath.lib (86 B)

Amber Schneider - Nov 07, 2023, 1:25 PM CST

Download

QEI.h (8.29 kB)

Amber Schneider - Nov 07, 2023, 1:25 PM CST

Download

QEI.cpp (9.27 kB)

Amber Schneider - Nov 07, 2023, 1:25 PM CST

Download

main.cpp (2.94 kB)

2023/10/27 Sinusoidal Motor Programming 1

Amber Schneider - Nov 07, 2023, 1:31 PM CST

Title: Sinusoidal Motor Programming 1

Date: 10/27/2023

Content by: Amber Schneider

Present: Kendra Besser

Goals: Hardcode given functions to run successfuly on mbed. Write a function to move the motor sinusoidally.

Content:

```
#include "mbed.h"

#include "QEI.h"

#include "math.h"

#include "ttmathbig.h"

#include <cstdio>

#include <math.h>

#include <stdlib.h>


//Serial pc(USBTX, USBRX); //how to connect to terminal? curently causing an error


// Setup for Encoder

QEI motorEncoder (D2, D3, D4, 5760,QEI::X4_ENCODING);

AnalogOut velocityControl(A2);

DigitalOut motorDirection(A0);

DigitalOut motorState(A1);


float hexaVelocity = 0.0;

float rpmVelocity;

float increment = 0;

float presicion = 0.015625;

float angle;
```

```
int demo;

int direction;

int state;

float  i = 0;

float sum;

float speed;




// Function to vary the motor speed sinusoidally

void sinusoidalSpeedVariation() {

    float amplitude = 25; //(maxRPM - minRPM) / 2.0;

    float offset = 0; //(maxRPM + minRPM) / 2.0;

    float frequency = 0.1; // Adjust the frequency as needed


    //int times [11] = {0,1,2,3,4,5,6,7,8,9,10}; // hardcode the time (in seconds)

    for (int currentTime : times) {

        // Calculate the current RPM using a sinusoidal function

        float rpmVelocity = amplitude * sin(2 * 3.14159265 * frequency * currentTime) + offset;

        hexaVelocity = 0.0063 * rpmVelocity;


        if(hexaVelocity<0) {

            motorDirection.write(0); //clockwise (-)

            hexaVelocity = hexaVelocity*-1;

        } else {

            motorDirection.write(1); //counter-clockwise (+)

        }

        velocityControl.write(hexaVelocity);

        if(currentTime > 60.0) {

            condition = false;
```

```
        }
        motorState.write(1);
        printf("End of loop \n");
    }
    printf("End of Function \n\n");
    motorState.write(0);
}



void incrementWrite()
{
    //printf("Enter a desired angle with a precision of 0.015625 degrees \n");
    //scanf("%f", &angle);
    angle = 90; // hardcode angle
    increment = rint(angle / presicion);
    //printf("Enter a rotational speed between 5 and 175 rpm \n");
    //scanf("%f", &rpmVelocity );
    rpmVelocity = 10; // hardcode rpmVelocity
    hexaVelocity = 0.0063*rpmVelocity;
    velocityControl.write(hexaVelocity);
    //printf("Enter 1 to start the motor rotation \n");
    //scanf("%d", &state);
    state = 1; //start motor rotation
    while (motorEncoder.getPulses() != increment) {
        if (motorEncoder.getPulses() < increment) {
            motorDirection.write(0); //clockwise
            motorState.write(1);
        }
        if (motorEncoder.getPulses() > increment) {
```

```
            motorDirection.write(1); //counter-clockwise

            motorState.write(1);

        }

        if (motorEncoder.getPulses() == increment) {

            motorState.write(0);

        }

    }

    motorState.write(0);

    printf(" Motor arrived at desired position \n\n");

}


void continuousMode()

{

    //printf("Enter a rotational speed between 5 and 175 rpm \n");

    //scanf("%f", &rpmVelocity);

    rpmVelocity = 10; // hardcoded

    hexaVelocity = 0.0063*rpmVelocity;

    velocityControl.write(hexaVelocity);

    //printf("Enter a rotational direction : 0 clockwise and 1 counterclockwise \n");

    //scanf("%d", &direction);

    direction = 0; //clockwise

    motorDirection.write(direction);

    //printf("Enter 1 to start the motor rotation \n");

    //scanf("%d", &state);

    state = 1;

    //printf("The motor will turn in the direction and the speed you chose \n\n");

    int i = 0; // run for 10 seconds

    while ( state == 1) {

        motorState.write(state);
```

```
        //printf("Enter 0 to stop the motor \n\n");
        //scanf("%d", &state);
        wait_us(1000000); // wait 1 s
        if (i==10) {
            state = 0;
        }
        else{
            i = i+1;
        }
    }
    motorState.write(0);
    printf(" Motor stopped \n\n");
}

int main()
{
    printf("Searching for initial position of the motor using the index of the encoder \n\n");

    while (motorEncoder.getRevolutions() != 1) {
        velocityControl.write(0.3f);
        motorState.write(1);
        motorDirection.write(0);
    }
    motorState.write(0);
    printf("Motor in initial position \n\n");
    motorEncoder.reset();
    wait_us(500000*2);
    //wait_ms(500); OUTDATED
```

```
    //incrementWrite(); // hardcoded version

    //continuousMode(); // hardcoded version

    sinusoidalSpeedVariation();




    // while(1) {

    //     printf("Enter 1 for angular positioning demo and enter 2 for speed and direction control demo \n\n");

    //     scanf("%d", &demo);

    //     if ( demo == 1) {

    //         incrementWrite();

    //         motorEncoder.reset();

    //     }

    //     if ( demo == 2) {

    //         continuousMode();

    //         motorEncoder.reset();

    //     }

    //     //break;

    // }

}
```

Conclusions/action items:

Code above successfuly moved the motor as expected. As for the sinusoidal motion, it is dependent on a list of predetermined "times". Future work includes using a clock/ time tracking library in C++ to have the motor continuously move sinusoidally.

2023/11/2 Sinusoidal Motor Programming 2

Amber Schneider - Nov 07, 2023, 1:37 PM CST

Title: Sinusoidal Motor Programming 2

Date: 11/2/2023

Content by: Amber Schneider

Present: Kendra Besser

Goals: get motor to run sinusoidally using continuous time

Content:

Library: <time.h> /* time_t, struct tm, difftime, time, mktime */

- use library to mark time outside the continuous loop, then measure time that has passed each time the loop runs
- `clock_t start = clock();`
- `clock_t end = clock();`
- `double currentTime = static_cast<double>(end - start) / CLOCKS_PER_SEC;`

Result

- **Motor moves continuously in a sinusoidal motion!**
- Stop condition: time exceeds 60 seconds

Conclusions/action items:

The motor moves as expected with the correct implementation of the library to track relative time. The file with correct functionality of this function is attached below (main.cpp). Future work includes getting the user input functionality to work as it did in Termite.

Amber Schneider - Nov 07, 2023, 1:36 PM CST

Download

main.cpp (5.14 kB)

2023/11/16 Motor User Input

Amber Schneider - Nov 17, 2023, 12:19 PM CST

Title: Motor User Input

Date: 11/16/2023

Content by: Amber Schneider

Present: Kendra

Goals: get user input functionality working

Content:

```
BufferedSerial pc(USBTX, USBRX); //how to connect to terminal
```

--

```
        printf("Enter 0 to Exit, Enter 1 for incrementWrite() hardcoded demo, Enter 2 for sinusoidal demo \n\n");
        char c;
        pc.read(&c, 1);
        int demo = c - '0';
```

Conclusions/action items:

Got user input functionality to work. Next steps include asking the client what inputs he would like to control for the sinusoidal function.

Amber Schneider - Nov 17, 2023, 12:19 PM CST

Download

main.cpp (6.18 kB)

2023/11/28 Final Testing Code

Amber Schneider - Dec 10, 2023, 2:56 PM CST

Title: Final Testing Code

Date: 11/28/2023

Content by: Amber Schneider

Present: Amber, Kendra

Goals: finish coding the testing protocols

Content:

Created functions to run the tests defined by the protocol.

Conclusions/action items:

Action items include running the desired test using mbed interface to generate data to be used during analysis. Full code is attached below.

Amber Schneider - Dec 10, 2023, 2:55 PM CST

Download

main.cpp (7.75 kB)

2023/09/13-Liver Fat Quantification by MRI Research Notes

Jamie Flogel - Sep 13, 2023, 2:11 PM CDT

Title: Notes on Total Liver Fat Quantification Using Three-Dimensional Respiratory Self-Navigated MRI Sequence

Date: 9/13/2023

Content by: Jamie Flogel

Present: N/A

Goals: Learn more about relevant information to get started with the project

Content:

Link:

https://onlinelibrary-wiley-com.ezproxy.library.wisc.edu/doi/pdfdirect/10.1002/mrm.26028

Citation:

C. Arboleda *et al.*, “Total liver fat quantification using three-dimensional respiratory self-navigated MRI sequence,” *Magnetic Resonance in Medicine*, vol. 76, no. 5, pp. 1400–1409, 2016, doi: 10.1002/mrm.26028.

Key Information:

-NAFLDS and AFLDs are the most prevalent chronic liver diseases worldwide

-These conditions can progress into chronic issues

-The gold standard for diagnosing these conditions is biopsy which is invasive and only allows us to look at small portions of the liver

-MRI is a promising technique to better diagnose these types of conditions

-MRI does not expose patients to harmful radiation and is much less invasive

-MRI can be used quantitatively

-Most imaging techniques being used are based off the Dixon principle

-Multiple images are acquired and fat and water signals are differentiated to produce a fat fraction

-This has been validated in animal models

-Slices are taken in one or multiple breath-holds

-Severely ill and pediatric patients are not always able to adequately perform these necessary breath holds

-Distribution of fat in the liver is not usually homogenous

-It would be extremely useful to compensate for breathing motions

-One current methodology includes adding a pneumatic device to monitor respiratory motion but this can shift its position

-Another method is using a beam that excited a column of spins which can trace translational motion

-This beam method does not require any external devices however they interrupt acquisition

-Navigator beams also may corrupt imaging data

-Phantoms are used to assess current techniques

-This article is analyzing a 3D respiratory self-navigation sequence

-The phantom contained different water-fat emulsions of varying fat concentrations

-Medicals doctors performed the fat fraction measurements

-Given the small number of samples statistical significance was difficult to verify

-Results showed promise

-Performing MRI without breath holds would increase patient comfort and reduce scan time

Conclusions/action items:

Quantitative MRI can be used to evaluate total liver fat. There are difficulties with motion due to breathing. Different methods are being used to address these issues. This establishes a need for a platform which can mimic the motion that researchers are trying to address.

2023/10/09- Respiratory Motion Induced Liver Movement Research Notes

Jamie Flogel - Oct 09, 2023, 4:04 PM CDT

Title: Notes on Respiratory motion estimation of the liver with abdominal motion as a surrogate

Date: 10/9/2023

Content by: Jamie Flogel

Present: N/A

Goals: Learn more about relevant information to model respiratory movement of the liver

Content:

Link:

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6282606/

Citation:

[1] S. Fahmi, F. F. J. Simonis, and M. Abayazid, "Respiratory motion estimation of the liver with abdominal motion as a surrogate," Int J Med Robot, vol. 14, no. 6, p. e1940, Dec. 2018, doi: 10.1002/rcs.1940.

Key Information:

-Respiratory motion estimation is done using external signals to simulate liver motion

-They utilized a machine learning approach to estimate the motion of the liver

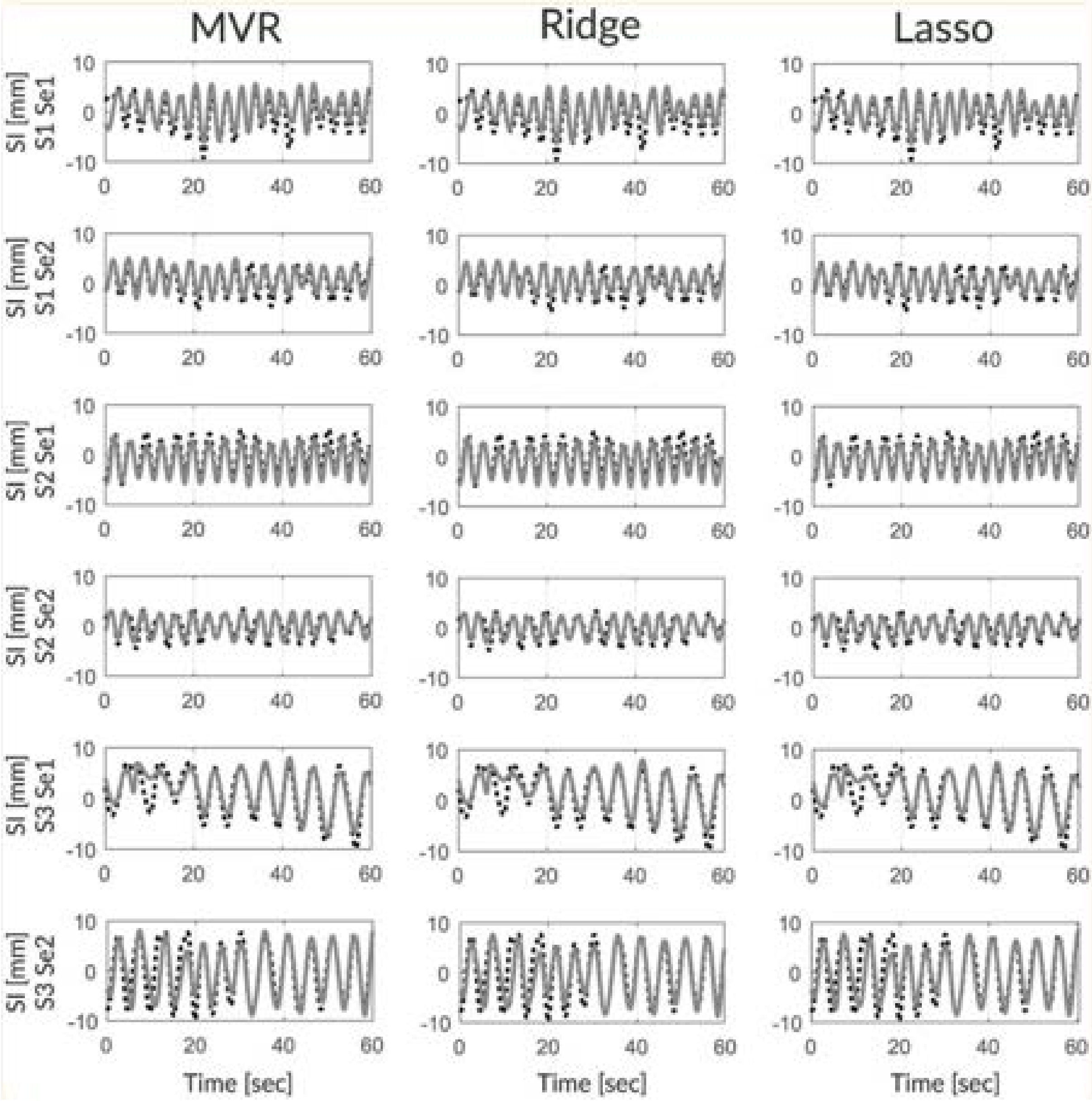
-They had a mean absolute error below 2mm

-Respiratory motion mainly affects organs in the abdominal and thoracic cavities

-Breath holds are usually used to get patient data without motion artifacts

-Breath hold techniques are not suitable for all patient populations

-They can use MR navigators, accelerometers or optical tracking as external signals for tracking

- 

-Liver follows a roughly sinusoidal motion

Conclusions/action items:

Respiration causes motion of internal organs like the liver which can cause signal defects in MRI scans. This supports the idea that by mimicking a sinusoidal waveform we can test out q-MRI protocols during liver movement. Our motion platform should be able to at least roughly mimic a sine wave.

2023/09/19-One-Dimensional Motion Competing Design Research Notes

Jamie Flogel - Sep 20, 2023, 2:23 PM CDT

Title: Notes on An MRI-Compatible Platform for One-Dimensional Motion Management Studies in MRI

Date: 9/19/2023

Content by: Jamie Flogel

Present: N/A

Goals:

-Learn more about existing products that serve similar functions

Content:

Link:

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6342555/

Citation:

[1] J. Nofiele *et al.*, "An MRI-Compatible Platform for One-Dimensional Motion Management Studies in MRI," *Magnetic resonance in medicine*, vol. 76, no. 2, p. 702, Aug. 2016, doi: 10.1002/mrm.25903.

Key Information:

-Study done to evaluate a programable one-dimensional motion system

-They used a system that had a programmable motorized linear stage and a computer

-They tested a phantom using this motion platform in the MRI environment

-The organ trajectories were based off of healthy volunteers

-They were able to asses the effects of motion on the quality of images and the accuracy of quantitative measurements

-They did not have any interference between the motion platform and the MRI

-The motion platform produced reliable linear motion within the whole body MRI machine

-This phantom was used to address abdominal motion

-Platform moved 5 cm in head/foot direction and 3 cm in the anterior/posterior direction

-Motion platform composed of a motorized linear stage inside the MRI and driving electronics outside the MRI room

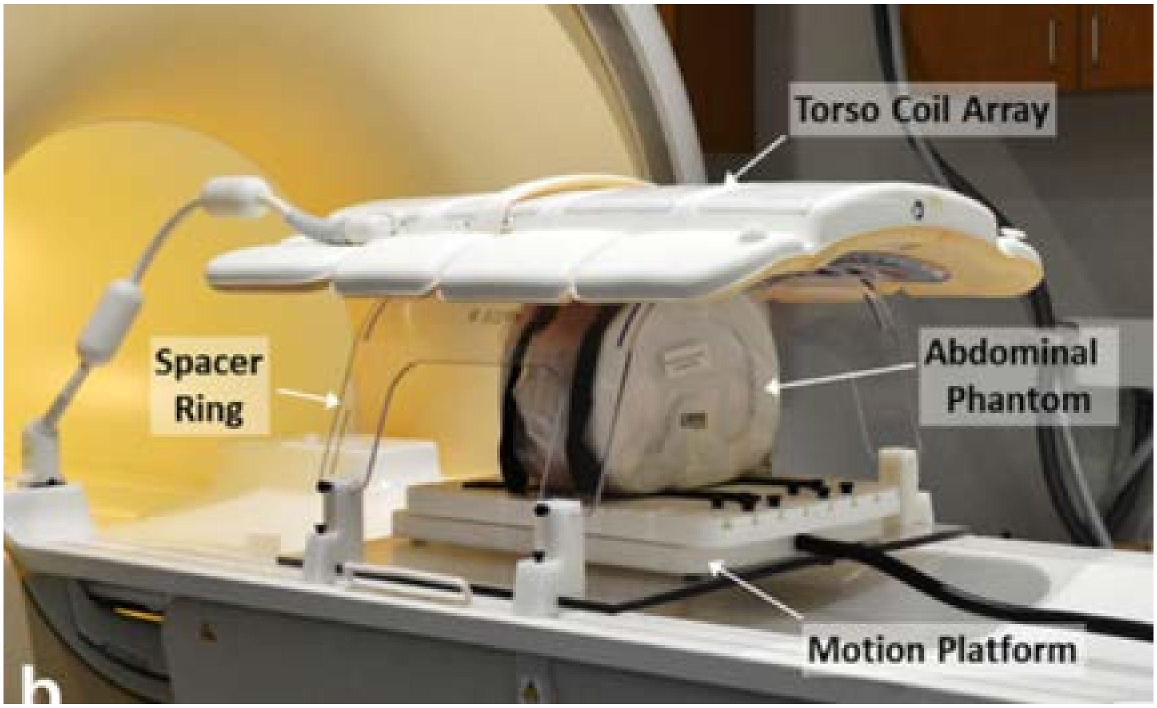
-The stage used 3 nonmagnetic linear bearing slides and was driven by piezoceramic motors

-Cables were connected to the driving electronics which had a motor amplifier, power supply and connector box

-Utilized a PCI-based motor controller

-Motion of the stage could mimic sinusoidal, harmonic, random or user-defined trajectories

-This was paired with an abdominal phantom



Conclusions/action items:

This design is very similar to what we want to accomplish with out design. This design was quite costly and is not a marketed product. Understanding what has been done to simulate motion in MRI will be helpful to determine which direction we should go with our design.

2023/09/20-Vital Competing Design Research Notes

Jamie Flogel - Sep 20, 2023, 3:20 PM CDT

Title: Notes on Vital Competing Design

Date: 9/20/2023

Content by: Jamie Flogel

Present: N/A

Goals:

-Learn more about what other MRI phantom competing designs are out there

Content:

Link:

https://vitalbt.com/wp-content/uploads/2015/07/MRI-Compatible-Multimodality-Motion-Stage_MR_1A_XRV2.pdf

or

https://www.simutec.com/Products/motionstages.html

Citation:

"Motion Stages Compatible with CT, MRI, PET, SPECT & Ultrasound." https://www.simutec.com/Products/motionstages.html (accessed Sep. 20, 2023).

Key Information:

-MR Safe motion phantom

-Linear motion stage for use inside the bore of an MRI

-User-defined trajectories

-Trajectories can be created in a spreadsheet template

-Loaded onto control system through a micro SD card

-Stage and motor are controlled outside the scanner room

-LCD on control unit provides updates on position of stage and the mode of operation

-Capable of superior-inferior and left-right linear motion

-Default motion is sinusoidal but a second default can be added

-Patent pending

-Wide use of applications

Accuracy in reaching a fixed position: 0.1 mm

-Maximum NRMSE for dynamic motion with frequency < 1 Hz: 6.0%

-Max speed: > 30 mm/sec

-Max force: ~> 20 N

-Max phantom weight/load: 6 kg

-Dimensions: 134 mm W X 72 mm H (90 mm with phantom adapter) X 287 mm L

-Carriage: 102 mm W X 95 mm L

-Range of motion: 50 mm (2.0")

-Max scanner field strength = 3 T

-Comes with other accessories

-Other devices by the same people to replicate other motions

Conclusions/action items:

This design is strong competition for meeting the needs of our client as it is able to mimic the motion of respirations. We should check in with the client to see what needs this product does not meet and what could be improved.

2023/09/20- Quasar Competing Design Research Notes

Jamie Flogel - Sep 20, 2023, 3:28 PM CDT

Title: Notes on Quasar Competing Design

Date: 9/20/2023

Content by: Jamie Flogel

Present: N/A

Goals:

-Learn more about what other MRI phantom competing designs are out there

Content:

Link:

https://modusqa.com/products/quasar-mri4d-motion-phantom/

Citation:

[Q] "QUASAR™ MRI^{4D} Motion Phantom," *Modus Medical Devices*. https://modusqa.com/products/quasar-mri4d-motion-phantom/ (accessed Sep. 20, 2023).

Key Information:

-MR Safe motion phantom

-Utilizes interchangeable inserts

-Utilizes piezoelectric motors

-Allows artifact-free imaging

-Utilizes an ultra-low latency controller (500 microseconds)

-Capable of complex motion

-Comes with software

-Programmable respiratory motion

-Can control phantom's motion, waveforms and reporting

-Allows users to test Deep Inspiration Breath Hold protocols

Conclusions/action items:

This competing design integrate the motion platform with the phantom. Designing a motion platform that is separate from the phantom is more aligned with our project goals and is a way to significantly reduce costs.

2023/09/11-Motion Phantom QIML Research Notes

Jamie Flogel - Sep 13, 2023, 12:30 PM CDT

Title: Notes on abstract on a past motion phantom QIML has made, using hydraulic instead of piezoelectric motor actuation

Date: 9/11/2023

Content by: Jamie Flogel, Article provided by client Mr. Jiayi Tang

Present: N/A

Goals: Learn more about relevant information to get started with the project

Content:

Link:

https://uwmadison.box.com/s/fp4knxj8nk4ww1j3frqtb91l75v0v2a0

Citation:

"Hydraulic Motion Phantom Abstract ISMRM 2023.pdf | Powered by Box." https://uwmadison.app.box.com/s/fp4knxj8nk4ww1j3frqtb91l75v0v2a0 (accessed Sep. 11, 2023).

Key Information:

-Certain methods of MRI can quantify markers for liver fat and iron deposition

-A phantom was constructed and validated using video tracking

-Chemical-Shift encoded (CSE) MRI is used to quantify proton-density fat fraction (PDFF) and R2

-PDFF is a biomarker for liver fat

-R2* is a biomarker for iron deposition

-Old methods required breath holding which is very limiting and leads to imprecise results

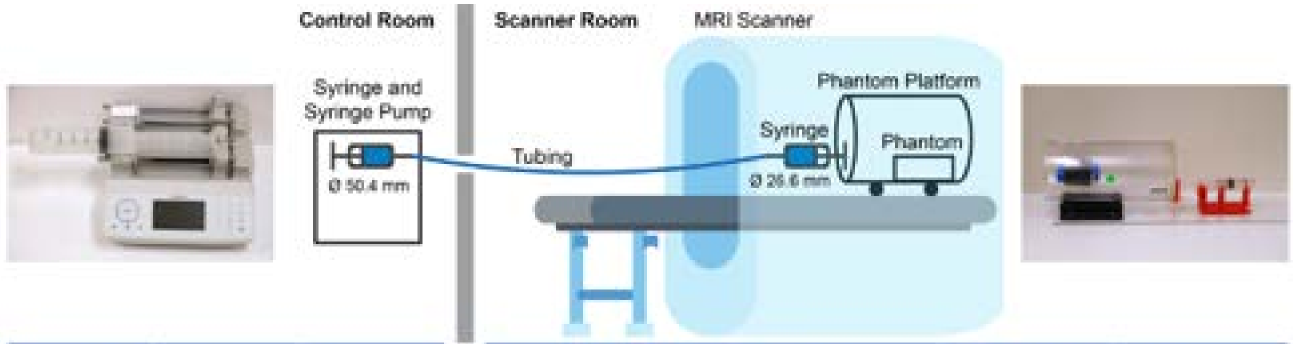
-Using motion-robust CSE we can allow for breathing and still get precise results

-Phantom was built using plastic components and a hydraulic connection

-Hydraulic connection was to a pump outside of the scanner room

-It used a syringe pump, acrylic phantom platform, syringes, tubing and holders/adapters

-4 rubberized wheels were utilized to facilitate motion



Motion profile	Motion+	Motion++
Frequency/ period	0.13 Hz = 7.7s per cycle	0.075 Hz = 13.3 s per cycle
Initial amplitude (mm)	12.7	32.2
Amplitude after 20 minutes (mm) (amplitude decreased over time, see Fig. 3)	10.7	30.1

Pulse sequence	3D-CSE	2D-CSE-FAM	SGRE
TE, echo time (ms)	TE_1 = 1.1, ΔTE=0.9, N_{TE}=6	TE_1=1.1, ΔTE=0.9, N_{TE}=6	1.4
TR, repetition time (ms)	7.2	9.7	3.2
Total bandwidth (kHz)	±62.5	±100.0	±83.3
Flip angle (degrees)	8	Variable[1]	20
Voxel size (mm × mm × mm)	2.0 × 2.0 × 4.0	2.0 × 2.0 × 4.0	2.0 × 2.0 × 4.0
Acquisition matrix size	128 × 128 × 40	128 × 128 × 30	128 × 128 × 3, with 30 repetitions
Acquisition duration (s)	21.4	39.2	37.7
Temporal footprint per slice (s)	21.4	1.3	0.4

-Different motions mimicked plausible amplitudes of normal liver motion

-Colored stickers were used to track with optical methods

-The phantom testing was performed inside commercially available MRI systems

Conclusions/action items:

Advanced MRI equipment is being tested to be able to quantify important measures such as liver fat and iron deposition. Phantoms were used to validate predicted results. Understanding more in this area of research will be useful in getting started with our project.

2023/09/12-Magnetic Resonance Imaging in Practice Research Notes

Jamie Flogel - Sep 13, 2023, 12:31 PM CDT

Title: Notes on past study which used a motion phantom to evaluate a MRI sequence.

Date: 9/12/2023

Content by: Jamie Flogel, Article provided by client Mr. Jiayi Tang

Present: N/A

Goals: Learn more about relevant information to get started with the project

Content:

Link:

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9792444/

Citation:

[1] R. Geng et al., “Motion-robust, blood-suppressed, reduced-distortion diffusion MRI of the liver,” Magnetic resonance in medicine, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9792444/ (accessed Sep. 12, 2023).

Key Information:

-Wanted to evaluate feasibility and reproducibility of liver diffusion-weighted MRI

-ADC mean and SD substantially increased with increasing motion in motion-affected volumes for monopolar waveforms

-ADC remained stable with increasing motion when motion-robust waveforms were utilized

-Combined M1-optimized diffusion waveforms and msEPI acquisitions allow reproducible liver DWI with motion robustness, blood signal suppression and reduced distortion

-DWI = diffusion-weighted imaging

-ADC = apparent diffusion coefficient

-msEPI = multishot echo planar imaging

-ssEPI = single-shot planar imaging

-Important for detection and monitoring of cancer in the liver

-ADC and other quantitative metrics are potential biomarkers for liver conditions

-Complication in DW-MRI come from signal dropouts due to physiological motion and image distortions

-Signal dropouts occur due to nonrigid tissue motion

-ssEPI is widespread but requires long readouts with significant distortions and limited resolution especially in the abdomen

-msEPI combined with specialized phase corrected reconstruction techniques can help to reduce distortion and allow for higher resolution

-They constructed a phantom to test out their ideas about combining techniques

-Synergistic combination of optimized, motion-robust DW waveforms with msEPI acquisitions produced low-distortion images without dropouts from motion

-This was the first time that the combination of these methods was verified

-Limitations of the study included number of subjects and the use of breath-held acquisitions

-Future work includes the use of free-breathing techniques with respiratory motion correction

-Additionally more sophisticated motion settings would be useful in better mimicking respiratory motion, cardiac motion and vessel pulsation

-Must also asses reliability and repeatability in other phantoms

-This research was done at UW-Madison

Conclusions/action items:

There is work being done to combine techniques to allow for low-distortion MRI images that do not contain dropouts due to motion. There is promise for the combination but more work needs to be done to refine and prove these findings. Understanding more about how phantoms are used with MRI will be useful in getting started with our project.

2023/09/29- Cam Design

Jamie Flogel - Sep 29, 2023, 10:20 AM CDT

Title: Cam Design Idea

Date: 9/29/2023

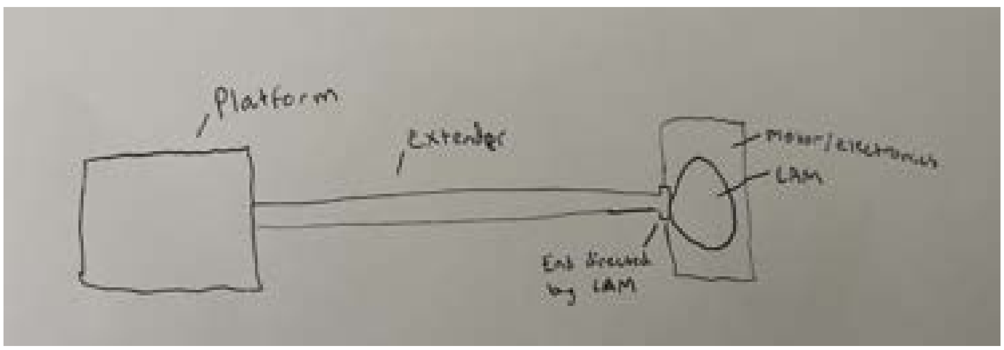
Content by: Jamie

Present: N/A

Goals:

-Document design idea

Content:



-Design idea separates the platform from the motor to reduce signal interference as much as possible

-The platform is connected via a long extender piece

-The end of the extender interacts directly with the CAM

-The CAM spins and the edge of the CAM pushes the extender pole to move the platform

-The shape of the CAM determines the amount and type of movement of the platform

-The CAM would be directly connected to a motor and the electronics used to power/program its motion

-It would take extensive work and careful fabrication to determine the exact shape of the CAM needed to produce the correct motion

-It may be difficult for others to replicate and reproduce this design

-Because of the emphasis on accessibility and repeatability in our project we determined this is not a top 3 contender

Conclusions/action items:

We discussed this designs idea while completing the design matrix and conclude it was not one of our three strongest designs. This design would require complex math making it difficult to fabricate and not very accessible for others to replicate.

2023/09/29- Slider Crank Design

Jamie Flogel - Sep 29, 2023, 10:33 AM CDT

Title: Cam Design Idea

Date: 9/29/2023

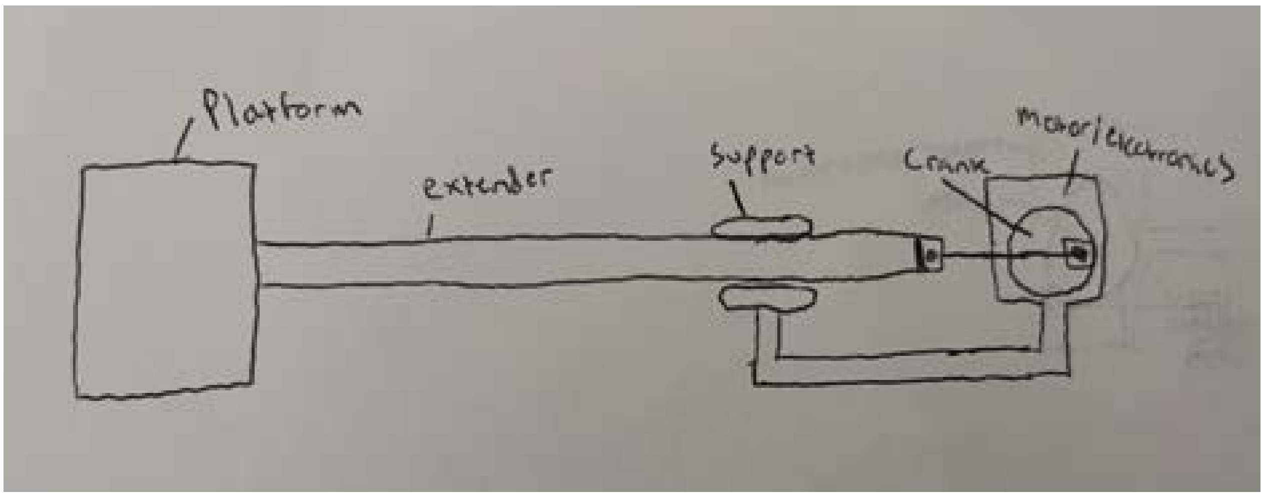
Content by: Jamie

Present: N/A

Goals:

-Document design idea

Content:



-Design idea separates the platform from the motor to reduce signal interference as much as possible

-The platform is connected via a long extender piece

-The extender motion is limited to one direction by the support piece

-The extender arm is connected to a rod which is fixed to the crank in one spot

-As the crank turns the rod pushes the extender arm which moves the platform

-The distance moved by the platform is determined by the size and speed of the gear as well as the rod length

-The crank motion is controlled by a motor and encased electronics

-We decided not to go forward with this design due to its similarity to the scotch yoke design

-This design takes up more room than the scotch yoke design while producing motion through a very similar mechanism

Conclusions/action items:

We discussed this designs idea while completing the design matrix and conclude it was not one of our three strongest designs. This design is similar to the Scotch Yoke design but takes up more space making it less desirable.

2023/10/18-Updated Gear Box

Jamie Flogel - Oct 18, 2023, 4:29 PM CDT

Title: Updated Gear Box

Date: 10/18/2023

Content by: Jamie Flogel

Present: N/A

Goals:

-Document changes to SolidWorks design of the gear box

Content:

-I worked off Max's initial SolidWorks drawing of the gear box

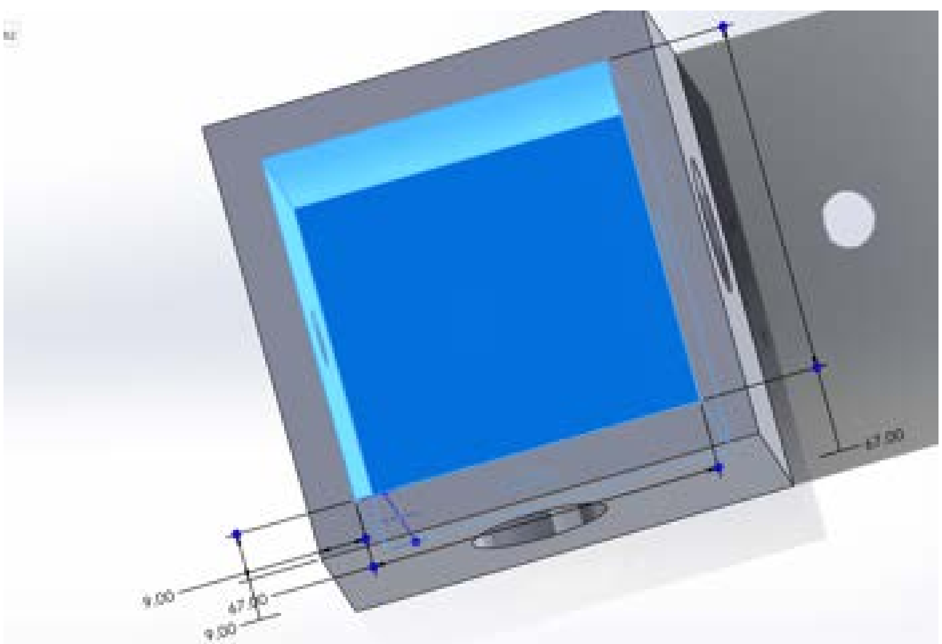
-I noticed in the assembly Max had the gears were directly mated to the inside walls of the gear box

-In order to prevent friction of the gears and the walls of the gear box I updated the dimensions

-I added 6 mm to the inner and outer side lengths

-They old design was a 79 x 79 mm box with and inner cut out of 61 x 61 mm

-The new design is 85 x 85 mm with an inner cut of 67 x 67 mm

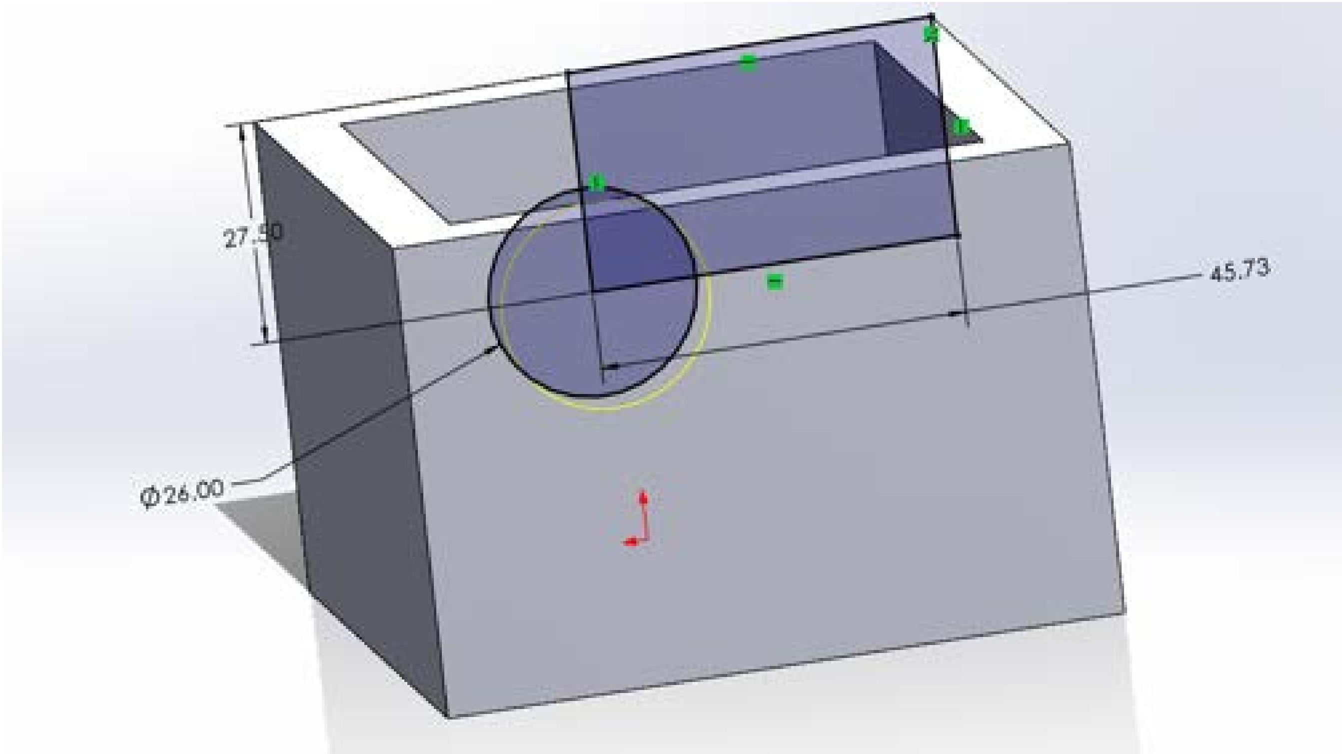


-I also adjusted the length between the outside corner of the box and the ball bearing center hole

-The old length from the center of the hole to the outer corner was 42.5 mm

-To calculate the new length I did (42.5 mm / 79 mm) * 85 mm to get a new length of 45.73 mm

-This adjustment should maintain the proper alignment of the gears



-File is attached below

Conclusions/action items:

I updated the dimensions of the gearbox to prevent friction. I will continue to work with Max to ensure everything is properly dimensioned before we 3D print.

Jamie Flogel - Oct 18, 2023, 4:29 PM CDT

Download

gearbox_JF.SLDPRT (123 kB)

2023/10/18-Updated Gear Box Assembly

Jamie Flogel - Oct 18, 2023, 4:52 PM CDT

Title: Updated Gear Box Assembly

Date: 10/18/2023

Content by: Jamie Flogel

Present: N/A

Goals:

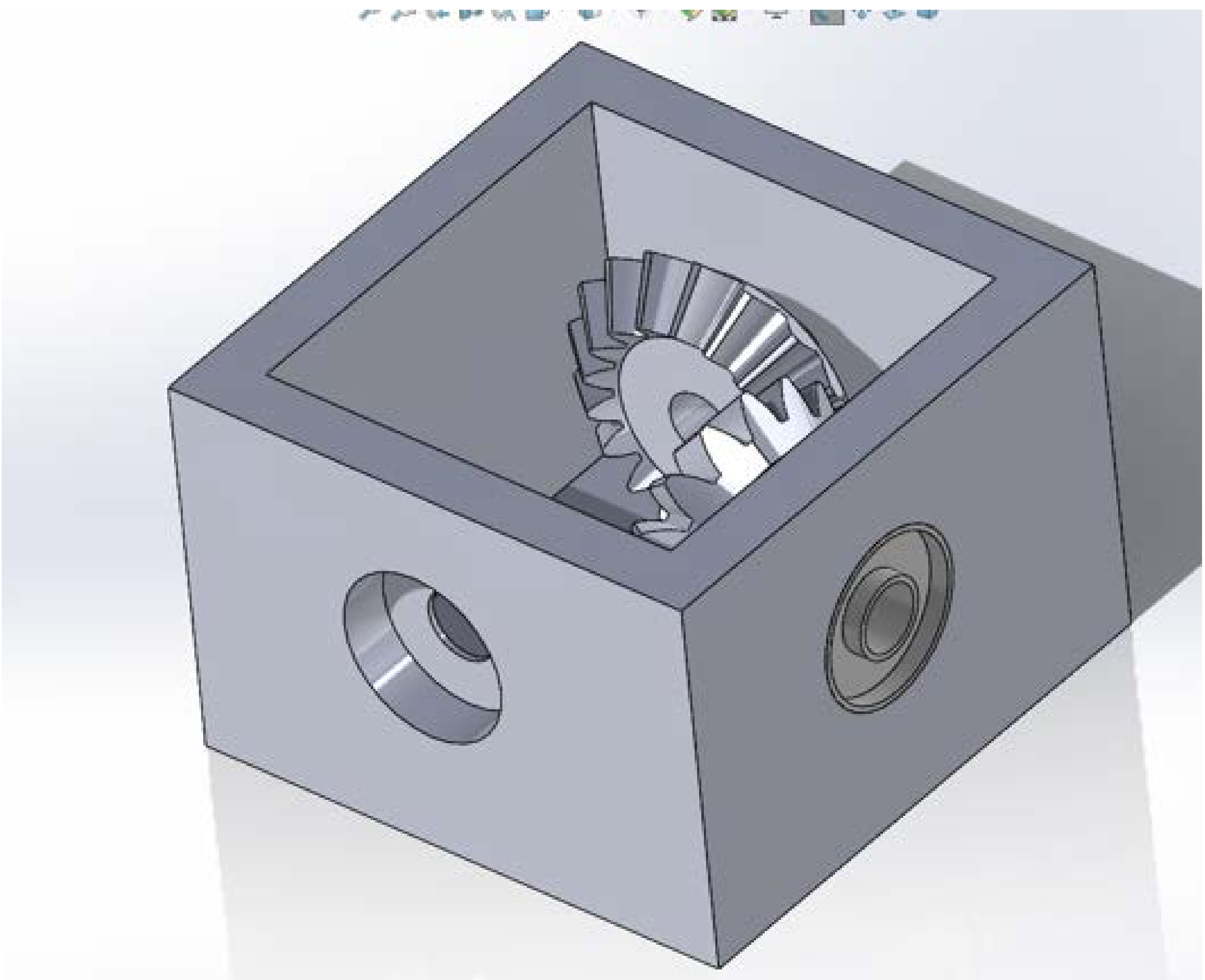
-Document changes to SolidWorks design

Content:

-I worked off Max's initial SolidWorks drawings and assemblies

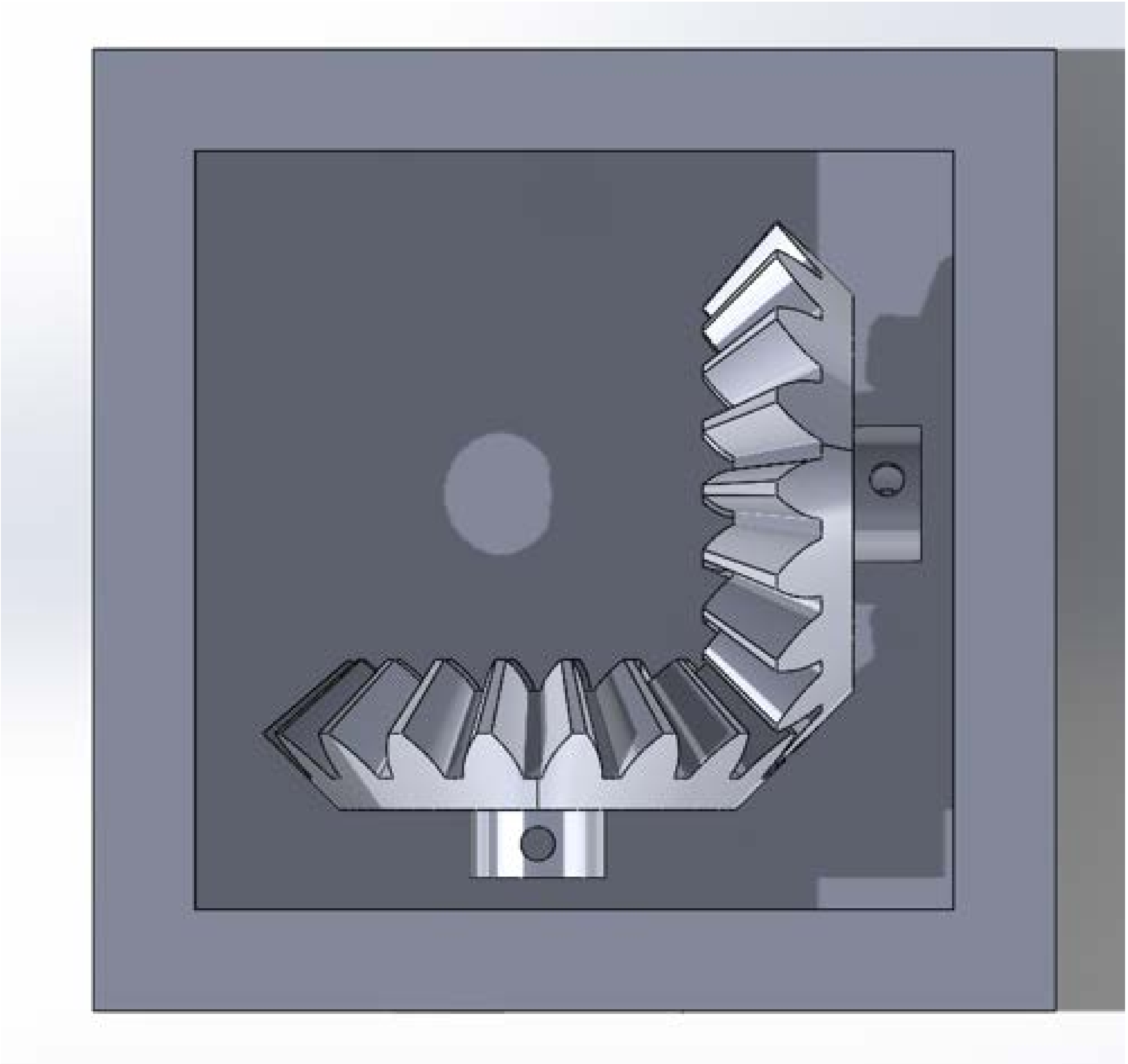
-I created a new assembly with the parts that I updated the dimensions

-It should look extremely similar to the old assembly with a few modifications



-The diameter of the bevel gears matches the ball bearings

-The gearbox is larger so there is not direct contact between the bevel gears and the box



Conclusions/action items:

I updated the dimensions of some of the components of the gearbox. I created a new assembly of these modified parts. Max and I will continue to make any necessary changes to the SolidWorks designs.

Jamie Flogel - Oct 18, 2023, 4:57 PM CDT

Download

GearboxAssem_JF.SLDASM (294 kB)

Jamie Flogel - Oct 18, 2023, 4:57 PM CDT

Download

BevelGear_JF.SLDPRT (720 kB)

Jamie Flogel - Oct 18, 2023, 4:57 PM CDT

Download

BallBearing.SLDPRT (99.7 kB)

Jamie Flogel - Oct 18, 2023, 4:57 PM CDT

Download

gearbox_JF.SLDPRT (122 kB)

2023/10/25- Drive Shaft Options

Jamie Flogel - Oct 27, 2023, 12:13 PM CDT

Title: Drive Shaft Options

Date: 10/25/2023

Content by: Jamie

Present: N/A

Goals:

-Look into options for purchasing a drive shaft

Content:

-In our current solidworks models the gear is driven by a 10 mm drive shaft

-Since our vendors have rods in inches not metric units we need to purchase a rod that is in inches

Approved vendors list: https://shopuwplus.wisc.edu/catalog-suppliers/

-The closest inch diameter would be 0.5 in diameter

-Since our client is UW affiliated we need to go through a shopuw approved vendor

-Likely Grainger or MSC would be best for purchasing plastics

-For MSC length options are 72 or 120

-For Grainger length options are 6, 8 or 10 ft

-72 inch length - 6 ft would likely be closer to what we want

MSC - Plastic Rod: 72″ Long, 0.5″ Dia, White, Opaque, 5000 - 1000 psi Tensile Strength

-Price = $25

-MSC# 94516168

-Expected to ship within 2 weeks

https://www.mscdirect.com/product/details/94516168

MSC - Plastic Rod: 72″ Long, 0.5″ Dia, Black, Opaque, 5000 - 1000 psi Tensile Strength

-Price = $15

-MSC# 94417219

-Expected to ship within 2 weeks

https://www.mscdirect.com/product/details/94417219

MSC - Plastic Rod: 72″ Long, 0.5″ Dia, Black, Opaque, 5000 - 1000 psi Tensile Strength

-Price = $12.48

-MSC# 94461001

-Expected to ship within 2 weeks

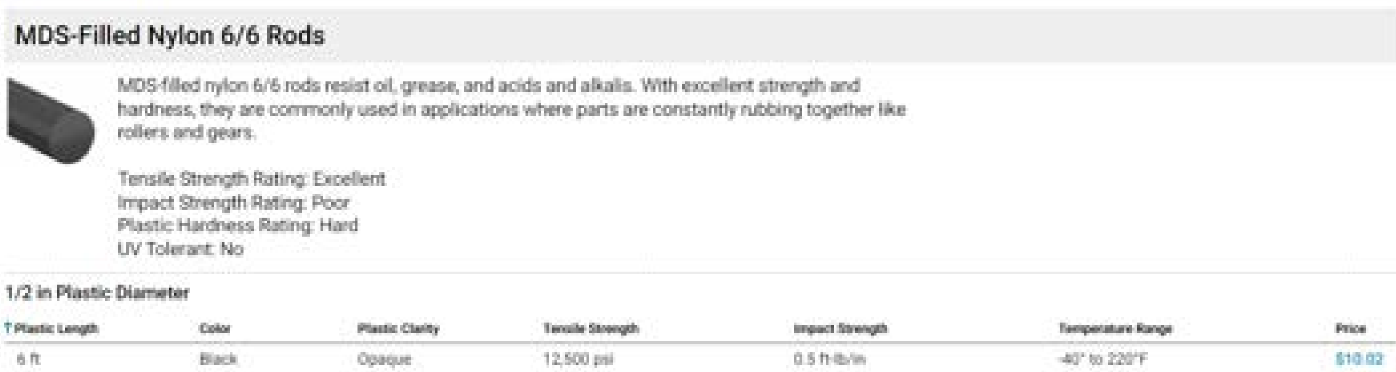
https://www.mscdirect.com/product/details/94461001

Grainger- Plastic Rod: 6 ft Plastic Lg, Black, Opaque, 12,500 psi Tensile Strength, -40° to 220°F, ±0.250 in

-Price = $10.02

-Temporarily unavailable

-https://www.grainger.com/product/GRAINGER-APPROVED-Plastic-Rod-6-ft-Plastic-Lg-2XPE5



MDS-Filled Nylon 6/6 Rods

MDS-filled nylon 6/6 rods resist oil, grease, and acids and alkalis. With excellent strength and hardness, they are commonly used in applications where parts are constantly rubbing together like rollers and gears.

Tensile Strength Rating: Excellent
Impact Strength Rating: Poor
Plastic Hardness Rating: Hard
UV Tolerant: No

1/2 in Plastic Diameter

Plastic Length	Color	Plastic Clarity	Tensile Strength	Impact Strength	Temperature Range	Price
6 ft	Black	Opaque	12,500 psi	0.5 ft-lb/in	-40° to 220°F	$10.02

Plastic Rod: Acrylic, 6' Long, 1″ Dia, Clear

-Price = $28.66

-Available to ship next day

https://www.mscdirect.com/product/details/63392344

Conclusions/action items:

There a number of different options for purchasing a plastic rod to use as the drive shaft. The purchased material would likely have to be modified to best fit our design due to unit mismatch.

2023/11/29-Updated Rack Design

Jamie Flogel - Nov 29, 2023, 3:19 PM CST

Title: Updated Rack Design

Date: 11/29/2023

Content by: Jamie Flogel

Present: N/A

Goals:

-Update existing rack to fit within the new dimensions since we updated the platform

Content:

See updated platform and rack files below

Conclusions/action items:

We will go ahead with printing the rack and screw it in. We can then assemble the entire prototype.

Jamie Flogel - Nov 29, 2023, 2:55 PM CST

Download

NewPlatform.SLDPRT (87.2 kB)

Jamie Flogel - Nov 29, 2023, 3:20 PM CST

Download

Rack.SLDPRT (242 kB)

Jamie Flogel - Nov 29, 2023, 3:20 PM CST

Download

Rack.STL (34.9 kB)

Jamie Flogel - Dec 01, 2023, 1:24 PM CST

Download

MotorStand.STL (46.7 kB)

Jamie Flogel - Dec 01, 2023, 1:24 PM CST

Download

MotorStand.SLDPRT (101 kB)

2023/09/13-Training Documentation

Jamie Flogel - Sep 13, 2023, 1:47 PM CDT

Title: Training Documentation

Date: 9/13/2023

Content by: Jamie Flogel

Present: N/A

Goals: To demonstrate completion of biosafety and chemical training

Content:

WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

This certifies that Jamie Flogel has completed training for the following course(s):

Course	Assignment	Completion	Expiration
Biosafety Required Training	Biosafety Required Training Quiz 2022	1/23/2022	1/23/2027
Chemical Safety: The OSHA Lab Standard	Final Quiz	1/23/2022	

Data Last Imported: 09/13/2023 01:42 PM

Conclusions/action items:

I have completed all required biosafety and chemical safety training.

2023/09/13-Green Permit Documentation

Jamie Flogel - Sep 13, 2023, 1:48 PM CDT

Title: Green Permit Documentation

Date: 9/13/2023

Content by: Jamie Flogel

Present: N/A

Goals: Document completion of green permit.

Content:

Conclusions/action items:

I have completed my green and red permit training.

Jamie Flogel - Mar 30, 2022, 7:24 AM CDT

Download

Green_Permit.jpg (64.6 kB)

2023/09/15 - MR-Compatible Motors

MAXWELL NASLUND - Sep 15, 2023, 11:20 AM CDT

Title: MR-Compatible Motors

Date: 2023/09/15

Content by: Maxwell Naslund

Present: N/A

Goals: Begin research into MR-Compatible materials for our motorized stage

Citation:

[1] Y. Chen, K.-W. Kwok, and Z. T. Tse, “An MR-conditional high-torque pneumatic stepper motor for MRI-guided and robot-assisted intervention,” *Annals of Biomedical Engineering*, vol. 42, no. 9, pp. 1823–1833, 2014. doi:10.1007/s10439-014-1049-x

Content:

Outlines several motor option:

1. Intrinsically MR-conditional actuators
    1. Mechanical actuators
    2. Pneumatic actuators
    3. hydraulic actuators
2. Electric actuators
    1. Piezoelectric motors
    2. Ultrasonic motors
3. Electromagnetic actuators
    1. MR-powered actuators

Electromagnetic and piezoelectric actuators utilize electric current to drive the actuators and will decrease the Signal to Noise Ratio of the MRI's and will lower the overall quality of the scans.

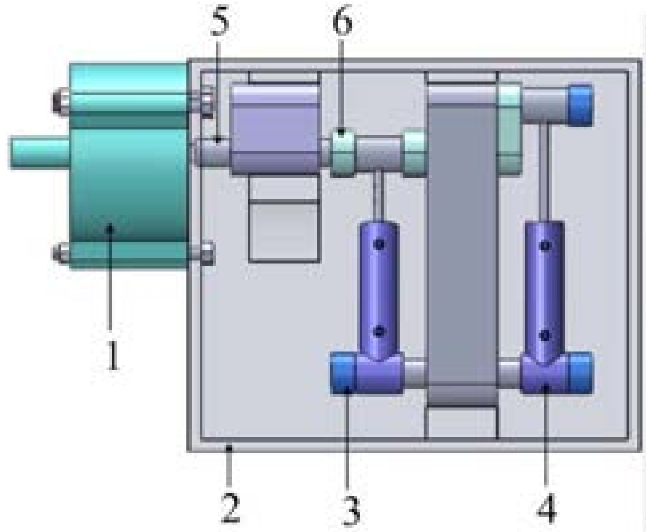
Electromagnetic and piezoelectric actuators also have to be properly shielded and placed in a safe location from the MR machine, which makes these options difficult to work with.

This article makes reference to an interesting solution that had recently been developed at the time of this article, that utilizes a motor that actually converts the static magnetic field of the MR machine itself into mechanical energy. This method, however, does not seem to be stable and has high variance on output.

With these considerations in mind, the article leans towards utilizing either hydraulic or pneumatic driven motors.

hydraulic actuators have the risk of leaking in the MR machine, so the best option seems to be using pneumatic pressure. The article makes note that air pressure supply is readily available in MR rooms.

This article proposes a new design with a working principle using conventional pneumatic pressure for a stepper motor.



Part	Component Name
1	Planetary gearbox
2	Supporting structure
3	Connecting bush
4	Cylinder
5	Shaft
6	Crank

Image 1: Proposed pneumatic stepper motor.

The image above illustrates the designed stepper motor from the paper. This motor would be guaranteed MR compatible and uses pneumatic pressure which is readily available in MR rooms.

The design itself is estimated to be less than $10 to construct.

Conclusions/action items:

The motor proposed in this paper is something that we should really look further into. If the provided ultrasonic motor from our client proves to be too difficult to use, or not efficient, then this would easily be our next best bet.

2023/10/11 - Respiratory motion estimation of the liver with abdominal motion as a surrogate

MAXWELL NASLUND - Oct 11, 2023, 3:31 PM CDT

Title: Respiratory motion estimation of the liver with abdominal motion as a surrogate

Date: 2023/10/11

Content by: Maxwell Naslund

Present: N/A

Goals: Detail some of the important aspects of this paper for our project

Citation:

[1] S. Fahmi, F. F. J. Simonis, and M. Abayazid, "Respiratory motion estimation of the liver with abdominal motion as a surrogate," *The International Journal of Medical Robotics and Computer Assisted Surgery*, vol. 14, no. 6, 2018. doi:10.1002/rcs.1940

Content:

The biggest thing to draw from this article is the graphical representation of the movement the liver undergoes from respiratory motion.

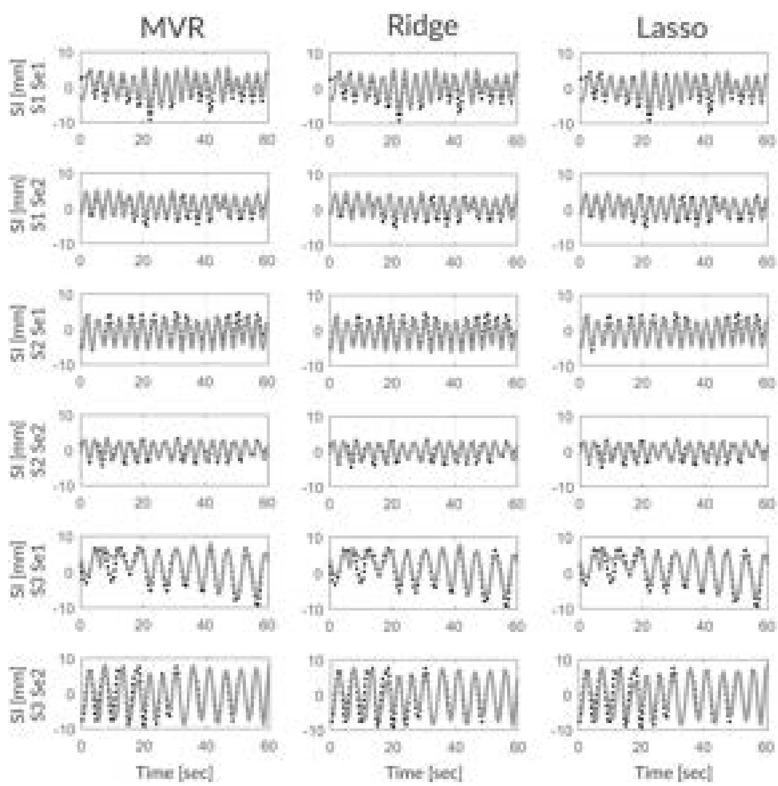


Figure1: Graphical representation of liver motion

Figure 1 above gives a perfect representation of what we need to replicate in our motion platform. The different columns seen here simply represent the three different regression models they used to consolidate this data. We should be able to extrapolate this data and utilize it to help redefine our required waveforms for the motion platform.

Conclusions/action items:

We will likely look towards this article to further detail the producible waveforms for the MR-compatible motion platform.

2023/9/21 - Small Phantom Test Guidance

MAXWELL NASLUND - Sep 22, 2023, 11:52 AM CDT

Title: Small Phantom Test Guidance Notes

Date: 2023/9/21

Content by: Maxwell Naslund

Present: N/a

Goals: Takes some notes on the American College of Radiology MRI accreditation program for small MRI phantoms

Citation:

[1] “MRI accreditation program,” AMERICAN COLLEGE OF RADIOLOGY, https://www.acraccreditation.org/-/media/ACRAccreditation/Documents/MRI/SmallPhantomGuidance.pdf (accessed Sep. 22, 2023).

Content:

This document provides some information about the phantom tests that are part of the American College of Radiology Magnetic Resonance Imaging Accreditation Program.

The acceptance criteria outlined in this document are meant to be indicative of a minimum level of performance one can reasonably expect from a well functioning specialty MRI system.

The ACR small MRI phantom is a short, hollow acrylic cylinder of acrylic plastic closed at both ends. Theinside length is 100 mm; the inside diameter is 100 mm. It is filled with a solution of nickel chloride and sodium chloride: 10 mM $NiCl_2$ and 0.45% by weight aqueous NaCl. The separate vial is filled with 20 mM$NiCl_2$ but no aqueous NaCl.Inside the phantom are several structures designed to facilitate a variety of tests of scanner performance.These structures will be described as the tests in which they are used are discussed below.

The phantom portion of the MRI accreditation program requires the acquisition of a sagittal localizer andfour axial series of images. The same set of seven slice locations within the phantom is acquired in eachof the four axial series. These images are acquired using the scanner’s standard knee coil.

The scan parameters for the localizer and the first two axial series of images are fully detailed here, but the remaining third and fourth series of axial images is dependent on each sites own protocols.

There are seven quantitative tests made using measurements on the digital data. They are as follows:

1. Geometric accuracy
2. High contrast spatial resolution
3. Slice thickness accuracy
4. Slice position accuracy
5. Image intensity uniformity
6. Percent signal ghosting
7. Low contrast object detectability

Geometric accuracy

Assesses the accuracy with the dimensions the image represents and the known dimensions of the imaged subject.

- The article recommends measurement criterion are within plus or minus 2mm of their true values

High contrast spatial resolution

This test assesses the scanner's ability to resolve small objects when the contrast-to-noise ratio is sufficiently high that it does not play a role in limiting that ability. This test assesses the distinguishability of closely spaced small objects.

- The article states that the field of view and matrix size for the axial ACR series are chosen to yield a resolution of 0.8 mm in both directions. The measured resolution of both axial ACR series must be 0.8 mm or better.

Slice thickness accuracy

Assesses the accuracy with which a slice of specified thickness is achieved. The Prescribed slice thickness is compared with measured slice thickness.

- The article states that the measured slice thickness of both axial AXR series should be 5.0 mm plus or munus 0.7 mm. Errors greater than 1.0mm should fail.

Slice Position accuracy

The slice position accuracy test assesses the accuracy with which slices can be prescribed at specific locations utilizing the localizer image for positional reference.

- The magnitude of each bar length difference must be less than or equal to 5 mm.

Image intensity Uniformity

This measures the uniformity of the image intensity over a large water-only region of the phantom lying near the middle of the imaged volume and thus bear the middle of the knee coil.

- Image ghosting can cause image intensity variations and hence failure of this test. Ghosting sufficient to cause failure of this test will be readily apparent in the image, and likely will cause failure of another test such as percent signal ghosting.

Conclusions/action items:

2023/9/21 - FDA Testing and Labeling Medical Devices for Safety in the Magnetic Resonance (MR) Environment

MAXWELL NASLUND - Sep 21, 2023, 8:32 PM CDT

Title: FDA Testing and Labeling Medical Devices for Safety in the Magnetic Resonance (MR) Environment

Date: 2023/9/21

Content by: Maxwell Naslund

Present: n/a

Goals: Detail some of the FDA's recommendations for medical devices within MR environments

Citation:

[1] “Testing and labeling medical devices for safety in the magnetic ...,” U.S. FOOD & DRUG ADMINISTRATION, https://www.fda.gov/media/74201/download?attachment (accessed Sep. 22, 2023).

Content:

There are no FDA standards when it relates to medical devices within an MR environment. This document only outlines what they recommend for such devices.

MRI machines produce very intense magnetic fields, and we must be aware of the risks associated with building a device that has any level of magnetic materials.

The area of the most intense magnetic field is found towards the entrance of the MRI.

Standard ASTM F2052 provides a test method for the measurement of magnetically induced displacement force for parts that can be suspended from a string. Measuring the magnetically induced displacement force of a device is highly recommended by the FDA. This is to better understand the risks associated with the medical device within the MR environment.

A maximum magnetically induced displacement force of less than or equal to the gravitational force on the medical device is often used as a conservative acceptance criterion for implants. A greater magnetically induced displacement force may be acceptable for implants or medical devices that are fastened to a patient depending on the properties of the device.

Similarly, an acceptance criterion greater than the gravitational force could be used for a medical device that is not attached to a patient if a system is provided to prevent the device from entering the region in which it would become a projectile.

To mitigate the chance of projectiles being generated by devices outside the MR system bore, such as ventilators and anesthesia systems, it is recommended that these devices are permanently secured so they cannot be moved into the hazardous area. It is recommended to include dead-man brakes, gauss meters mounted on the medical device, and/or nonferromagnetic tethers.

The MR system's static magnetic field induces a torque on magnetic materials. This magnetically induced torque is proportional to the static magnetic field strength and is greatest inside the MR system bore where the static magnetic field strength is greatest.

ASTM F2213 provides standard methods for measuring magnetically induced torque for medical devices in the region of the uniform magnetic field in an MR system.

A maximum magnetically induced torque of less than or equal to the gravitational torque on the medical device is often used as a conservative acceptance criterion. A greater magnetically induced torque may be acceptable depending on how an external medical device is fastened to the patient or restrained from moving when it is within the MR environment.

RF Heating

The radiofrequency (RF) and time-varying gradient fields (dB/dt) of the MR system can induce heating of the tissue adjacent to the medical device and/or heating of the medical device itself. This hazard should be addressed for all medical devices anticipated to enter the bore of the MR system.

There are no standard methods for assessing RF induced heating in the MR environment for medical devices that are external and patient-contacting. These devices should include shielding materials, high permittivity blocks or dielectric pads that should be evaluated for RF safety because of the significant effects of these devices on the electric fields present around them.

Eddy Currents

Exposure to time-varying magnetic fields (gradient pulses) can induce eddy currents on conductive surfaces of conductive/metallic implants, and in the internal conductive components of AIMDs placed inside the bore of the MR system. The power deposited by the magnetic field gradients is primarily determined by the surface area and thickness of the conductor, rate of change of the magnetic field, electrical conductivity, and the relative orientation of the conductive loops to the varying magnetic fields. The power deposited is also determined by the location in the bore, since the strength of the time-varying magnetic field changes with time and location.

In determining whether testing for gradient induced heating of a passive medical device is warranted, the following factors maybe useful to consider. All the following conditions need to be present for gradient induced heating of a metal implant to reach a clinically significant level: 1) large and symmetric surface area of the medical device, 2) dB/dt perpendicular to the large surface of the medical device, 3) large sustained gradient slew rate, and 4) the medical device is located in the region of the MR system bore where dB/dt is most intense.

Due to the rapid drop-off of the gradient fields outside the MR system bore, gradient induced heating does not pose a thermal hazard for medical devices located outside the bore.

Vibration risks

The MR system’s pulsed gradient magnetic fields, dB/dt, may induce forces on metallic medical devices that result in vibration of the device. This gradient induced vibration may lead to device malfunction or tissue damage.

All the following conditions need to be present for gradient induced vibration of a metal implant to reach a clinically significant level: 1) large and symmetric surface area of the medical device, 2) dB/dt perpendicular to the large surface of the implant, 3) large sustained gradient slew rate, and 4) implant is located in the region of the MR system bore where dB/dt is most intense.

Acceptance criteria for gradient induced vibration should be established based on the locationof the medical device in or on the body and the location inside the magnet using a scientific rationale or existing literature. The acceptance criteria should address the potential for tissuedamage and device malfunction for specific functions of the medical device.

Gradient Induced Extrinsic Electrical Potential

The time-varying gradient magnetic fields associated with an MR exam can induce an electric potential at the electrodes of a lead. The induced voltage can generate currents that can cause unintended physiologic stimulation or medical device malfunction.

Acceptance criteria should be established based on the location of the medical device in or onthe body and the location in the MR system bore using a scientific rationale or existing literature.

Extent of Image Artifact

The presence of metallic implants or other medical devices can lead to artifacts in the acquiredMR images. The operation of an active medical device may lead to artifacts or corruption of the acquired MR images. Both can lead to uninterpretable or non-diagnostic images or disease mimicking artifacts.

ASTM F2119 provides a standardized test method for the assessment of susceptibility image artifact. While the scope of this standard is passive implanted medical devices, the method can also be applied to AIMDs, partially implanted medical devices, or non-implanted medical devices that are anticipated to be in the MR system bore.

For electrically active medical devices that do not enter the MR system bore,Electromagnetic Compatibility (EMC) emissions should meet criteria defined for the special environment35 as specified by the MR system manufacturer.36 While no standardized test methods currently exist to assess image artifact produced by electrically active medical devices that do not enter the MR system bore, a qualitative assessment of image quality and a measurement of signal to noise ratio (SNR) using standardized test methods (such as NEMAMS 137) with and without the medical device present may be useful.

Device Labeling

Device labeling must satisfy all applicable FDA labeling requirements including, but not limited to , 21 CFR part 801. The device should also sufficient information for healthcare professionals to determine if the device is safe to enter the MR environment.

you should label your medical device as MR Safe, MR Unsafe, or MR Conditional, and include the appropriate symbol from ASTM F2503.

Conclusions/action items:

MAXWELL NASLUND - Sep 21, 2023, 8:33 PM CDT


Testing and Labeling Medical Devices for Safety in the Magnetic Resonance (MR) Environment

Guidance for Industry and Food and Drug Administration Staff

U.S. FOOD & DRUG

Download

Testing-Labeling-MRI-Envrionment-Guidance.pdf (866 kB)

2023/10/09 - Brainstorm preliminary ideas

MAXWELL NASLUND - Oct 09, 2023, 6:22 PM CDT

Title: Brainstorm preliminary ideas

Date: 2023/10/09

Content by: Maxwell Naslund

Present: n/a

Goals: Outline some preliminary ideas for designs

Content:

One of the biggest problems we as a team will have to overcome, is how we will translate the rotational motion of the provided motor to linear motion that we can control. After some initial research, I have discovered a mechanism called the scotch yoke that I think would be useful in this design. The scotch yoke features a round element that rotates. This round element has a pin that protrudes from one of the sides. There is another component that is locked to move in only one dimension. This other component also has an elongated empty space within it where the pin of the round element would sit. As the round element spins, the pin would forcefully drag the other element and as it is locked to one dimensional movement, it will oscillate back and forth as the round element rotates.

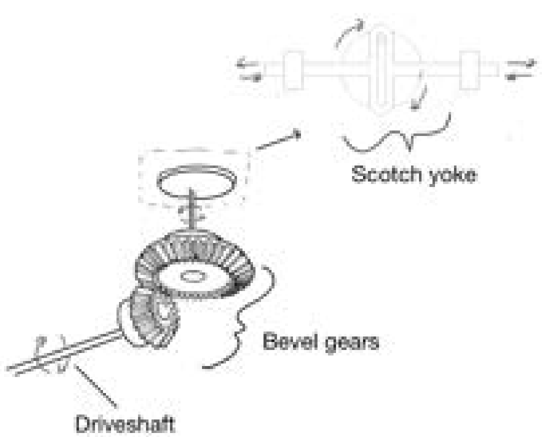


Figure 1: Preliminary Idea 1

Figure 1 above illustrates how this device would function as a whole. In essence, the motor would sit at the end of the MRI bed. The motor would be connected to a driveshaft which will translate its rotational movement down into the MRI itself. From here, the rotational movement of the motor would be shifted to a tangent plane up. Here the rotational motion could be translated to the round element of the scotch yoke. The linear element of the scotch yoke would then be connected to a bed that our MR phantoms could sit.

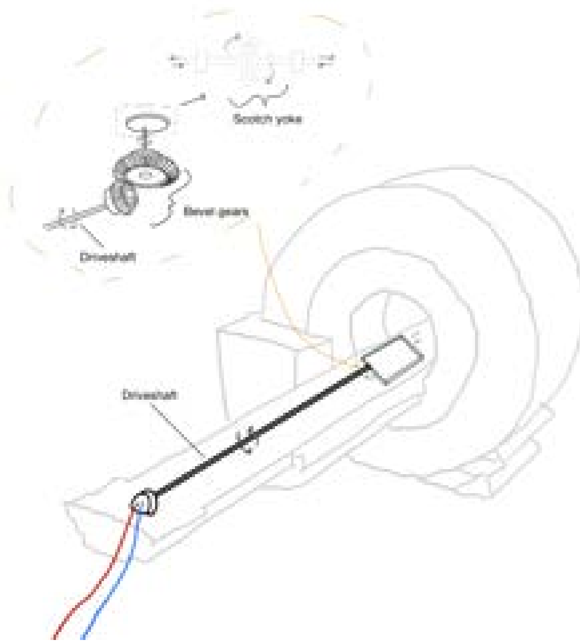


Figure 2: Preliminary Idea 1 Full

Figure 2 above illustrates how the entirety of the device would function on the MRI. Here we see how the motor itself will sit at the end of the MRI bed. This is to avoid any negative effects to the MR images themselves. The driveshaft then translates this motion down the bed to where the bevel gears shift the rotational motion. The rotational motion is then converted to linear motion via the scotch yoke. This will then oscillate the phantom bed back and forth depending on the sinusoidal wave set by the scotch yoke.

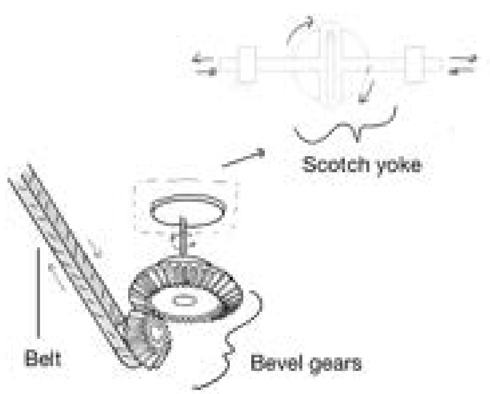


Figure 3: Preliminary Idea 2

Figure 3 above illustrates another way how we could transfer rotational motion down the MRI bed to the bevel gears. This method utilizes a belt instead of a driveshaft to shift rotational motion. This design would help reduce calculations related to torsional stress created on the driveshaft itself, but would likely require more material to maintain tension of the belt.

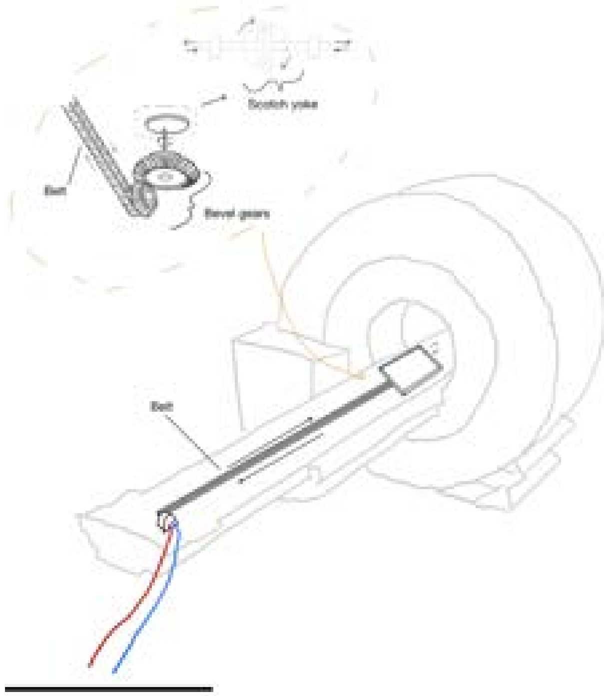


Figure 4: Preliminary Idea 2 Full

Figure 4 above illustrates how the belt design would be utilized in the MRI machine itself. Lots of material would be necessary beneath the belt to maintain tension on the best, but this eliminates torsional strain on created on a driveshaft.

Conclusions/action items:

I will present these two preliminary ideas to the team and get their thoughts on their advantages and disadvantages. Moving forward, I think the driveshaft idea would be our best bet.

2023/10/09 - Preliminary Idea 1 Redrawn

MAXWELL NASLUND - Oct 09, 2023, 6:08 PM CDT

Title: Preliminary Idea 1 Redrawn

Date: 2023/10/09

Content by: Amber/Maxwell

Present: N/A

Goals: Redrawn selected preliminary design 1

Content:

The team has met and successfully decided on three preliminary designs. The first of the three is the lead screw design. This design was presented by Amber, but I will take the effort to redraw this design to match the other two. This design similar to my preliminary brainstormed idea, will utilize a driveshaft to transfer rotational motion from the motor down into the MRI machine. The end of the driveshaft will be a threaded lead screw. When the driveshaft is rotated by the motor, the lead screw will thread through a component attached to the phantom bed that will forcefully move the bed in a linear motion dependent on the direction of the rotation and the speed of the rotation.

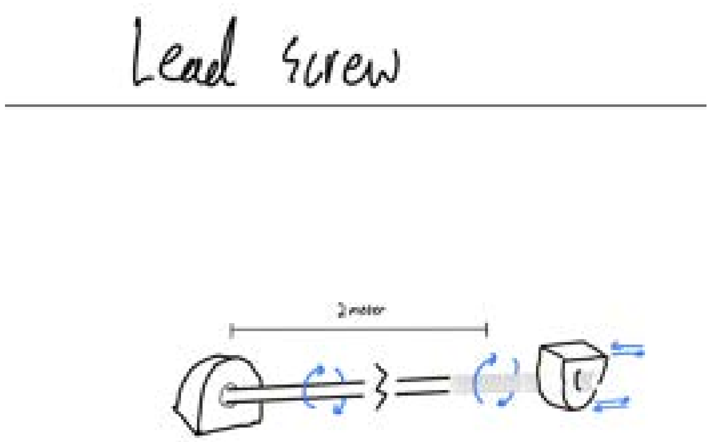


Figure 1: Lead Screw Redrawn

Figure 1 illustrates the redrawing of the teams preliminary design 1 (Lead Screw). The entire length of the driveshaft/lead-screw will be 2 meters. This will allow the motor to be completely separated from MRI, while also transferring its rotational motion into the MRI.

Conclusions/action items:

This redrawing of the Lead Screw design will be what we use in the design matrix and in our preliminary report.

2023/10/09 - Preliminary Idea 2 Redrawn

MAXWELL NASLUND - Oct 09, 2023, 6:21 PM CDT

Title: Preliminary Idea 2 Redrawn

Date: 2023/10/09

Content by: Maxwell Naslund

Present: N/A

Goals: Outline the redrawing of preliminary design 2

Content:

This is the preliminary design idea that I presented. The overall design is exactly the same as the one I outlined in my brainstorming section.

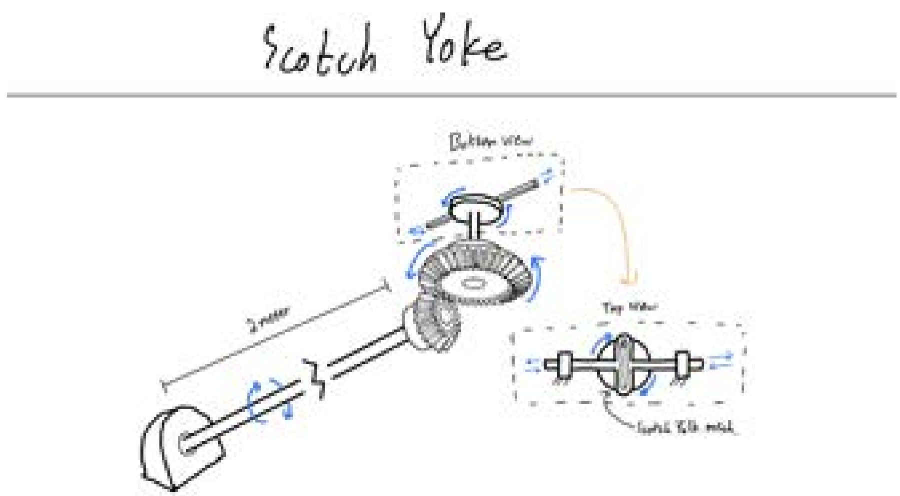


Figure 1: Preliminary Design Idea 2 Redrawn

Figure 2 above shows the slight modification to my brainstormed preliminary idea I presented. After consulting with the team, we decided to move forward with the driveshaft design opposed to the belt design.

Conclusions/action items:

This is the image that we will use in our design matrix/preliminary presentation/preliminary report.

2023/10/09 - Preliminary Idea 3 Redrawn

MAXWELL NASLUND - Oct 09, 2023, 6:40 PM CDT

Title: Preliminary Idea 3 Redrawn

Date: 2023/10/09

Content by: Maxwell/Amber/Kendra

Present: N/A

Goals: Outline the redrawing of preliminary design 3

Content:

After meeting with the team to discuss our preliminary designs, Amber and Kendra both came up with the idea to use a rack and pinion to transfer our rotational motion to a linear motion. We as a team decided to move forward with this as our third preliminary design. Just to standardize the style and better detail how this design works I have spent time redrawing this design.

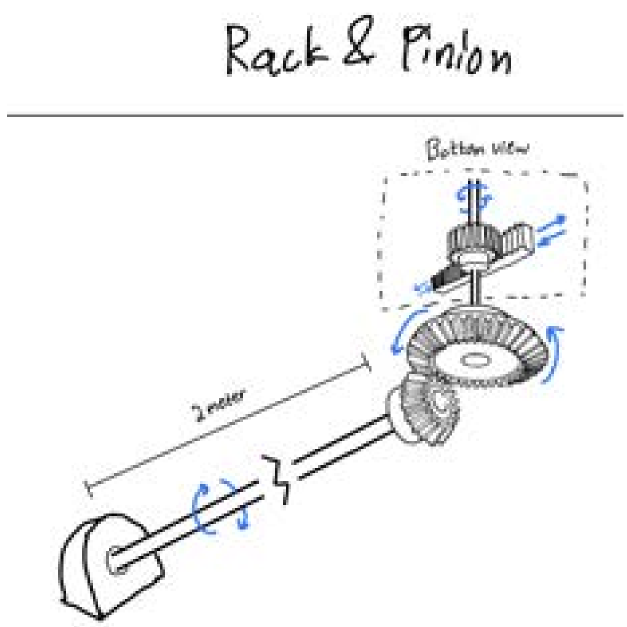


Figure 1: Preliminary Design Idea 2 Redrawn

Figure 1 above illustrates how the overall mechanism of the design would function. Rotational motion from the motor would be transferred down into the MRI via a driveshaft. This rotational motion would then be shifted to a tangent plane via some bevel gears. Here, instead of being attached to a scotch yoke mechanism, the rotation motion is transferred to a pinion. This pinion would rotate against a rack who's movement is locked to a single dimension. The phantom bed would then be attached to this rack. As the pinion rotates, this motion is translated to linear motion to the rack. The rack is attached to the phantom bed, so as the rack oscillates, so would the phantom bed.

Conclusions/action items:

This is the image that we will use in our design matrix/preliminary presentation/preliminary report.

2023/10/10 - Bevel Gear

MAXWELL NASLUND - Oct 09, 2023, 6:47 PM CDT

Title: Bevel Gear

Date: 2023/10/10

Content by: Maxwell Naslund

Present: N/A

Goals: Detail the dimensions of the bevel gear for our preliminary prototype

Content:

As the team has chosen to move forward with the rack and pinion design. I have begun to start designing a preliminary prototype in Solidworks for this project. Here I will detail the bevel gears that will be used for this design. As of right now, I have chosen to go with a gear ratio of 1:1.

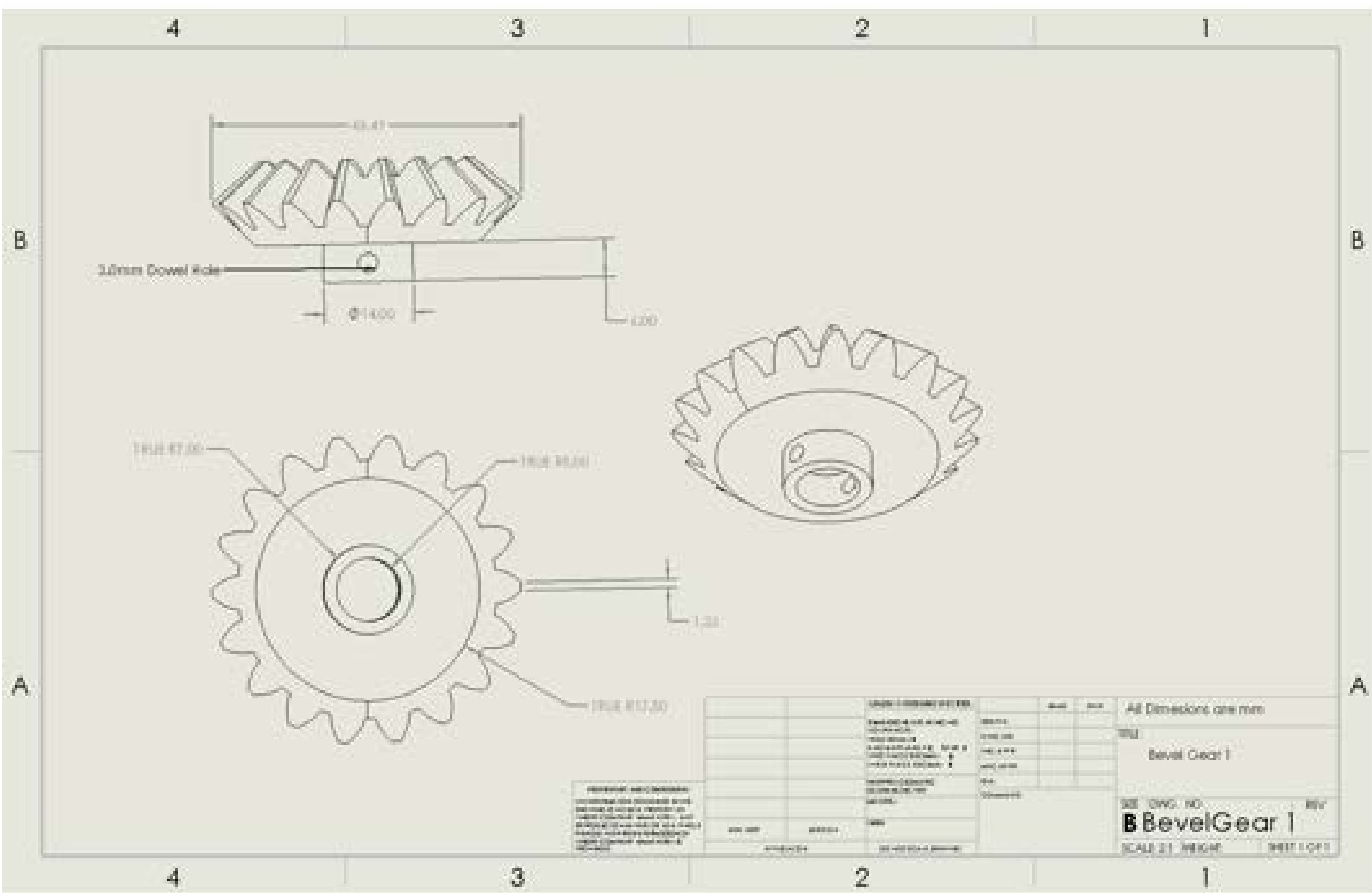


Figure 1: Bevel Gear 1

Figure 2 above reveals the selected dimensions of the bevel gear to be used in our 1:1 bevel gear box.

Conclusions/action items:

This will be the bevel gear that I will use in our preliminary design prototype.

MAXWELL NASLUND - Oct 09, 2023, 6:47 PM CDT

Download

BevelGear_1.SLDPRT (682 kB)

MAXWELL NASLUND - Oct 09, 2023, 6:47 PM CDT

Download

BevelGear_1.SLDDRW (355 kB)

2023/10/09 - Ball Bearing Model

MAXWELL NASLUND - Oct 09, 2023, 7:01 PM CDT

Title: Ball Bearing Model

Date: 2023/10/09

Content by: Maxwell Naslund

Present: N/A

Goals: Outline the dimensions of the model ball bearing

Content:

The client has provided the team with some glass ball bearings that are MR compatible. For the sake of modeling our prototype, I took measurements of these ball bearings and created a dummy model of these ball bearings in Solidworks. This will allow me to better understand how to incorporate these ball bearings into our design, and how to best utilize them.

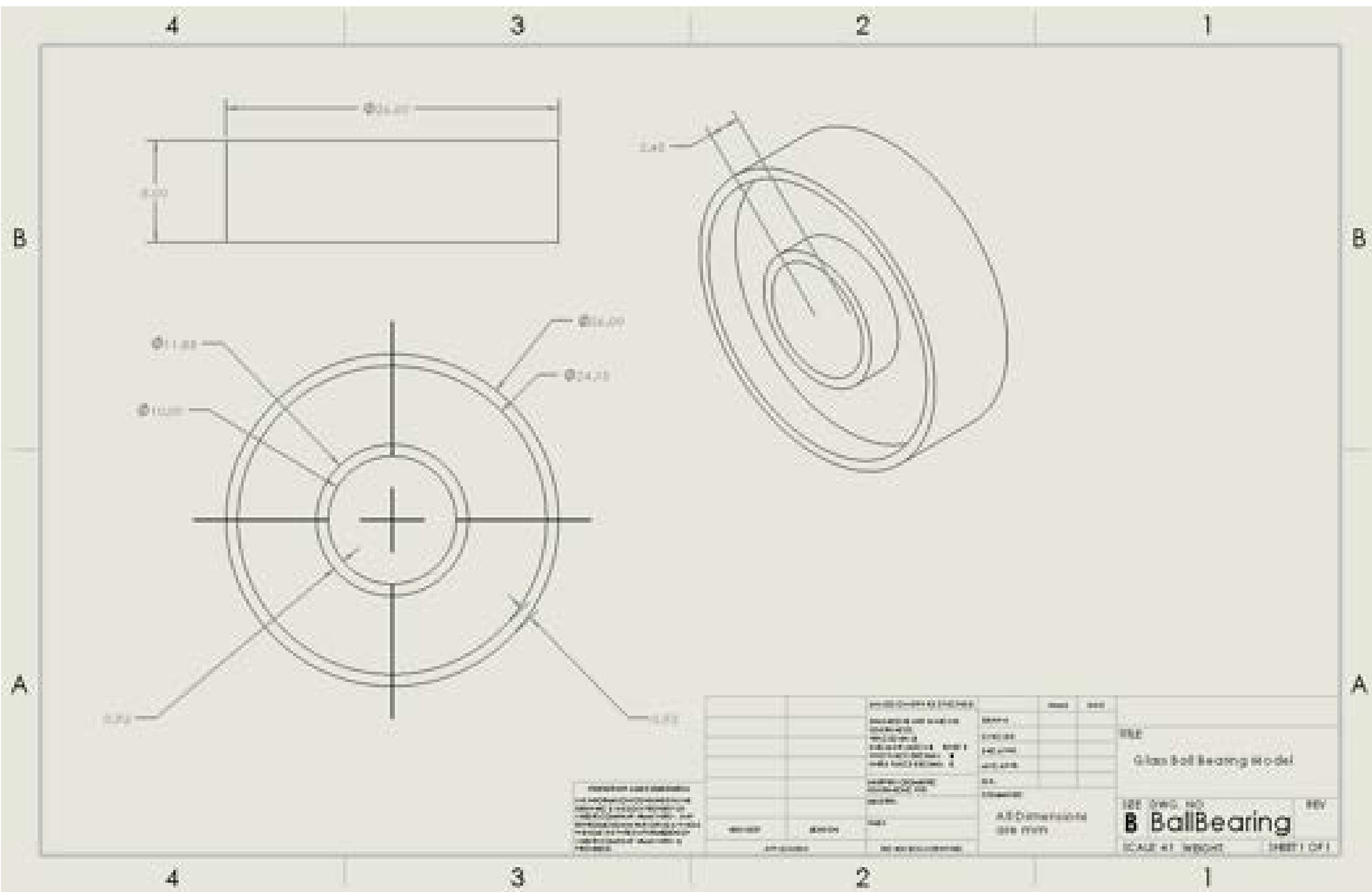


Figure 1: Ball Bearing Model

Figure 2 above illustrates some of the dimensions that I measured off of the glass ball bearings the client provided us with. The dimensions of the glass balls are not critical to the design, so I did not spend the time modeling them.

Conclusions/action items:

I will use this model in our preliminary prototype model.

MAXWELL NASLUND - Oct 09, 2023, 7:01 PM CDT

Download

BallBearing.SLDPRT (98 kB)

MAXWELL NASLUND - Oct 09, 2023, 7:01 PM CDT

Download

BallBearing.SLDDRW (128 kB)

2023/10/09 - Gearbox Model

MAXWELL NASLUND - Oct 09, 2023, 7:28 PM CDT

Title: Gearbox Model

Date: 2023/10/09

Content by: Maxwell Naslund

Present: N/A

Goals: Detail the dimensions of the gearbox to be used in the preliminary design prototype

Content:

This gearbox will be used to hold the 1:1 bevel gears. This gearbox will allow the rotational motion from the motor to be transferred to a tangent plane. This tangent plane will be where the rotational motion of the motor will be transferred into linear motion via the rack and pinion mechanism.

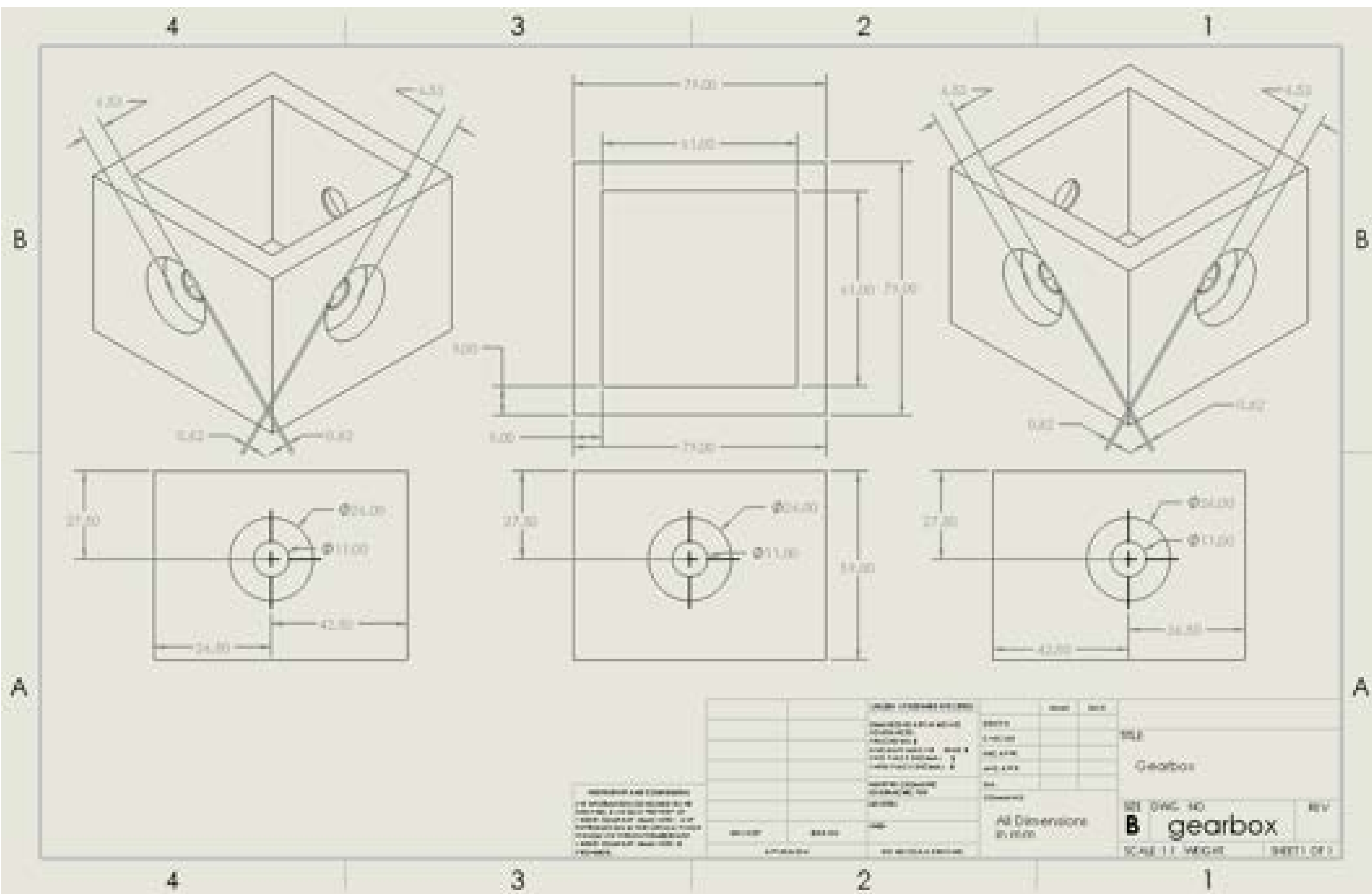


Figure 1: Bevel Gear Box model

Conclusions/action items:

Figure 1 above details the dimension of the gear box to be used in the preliminary design prototype.

MAXWELL NASLUND - Oct 09, 2023, 7:28 PM CDT

Download

gearbox.SLDPRT (108 kB)

MAXWELL NASLUND - Oct 09, 2023, 7:28 PM CDT

Download

gearbox.SLDDRW (159 kB)

2023/10/09 - Exploded Full Assembly

MAXWELL NASLUND - Oct 09, 2023, 8:18 PM CDT

Title: Exploded Full Assembly

Date: 2023/10/09

Content by: Maxwell Naslund

Present: N/A

Goals: Detail the overall Design of the Full Assembly

Content:

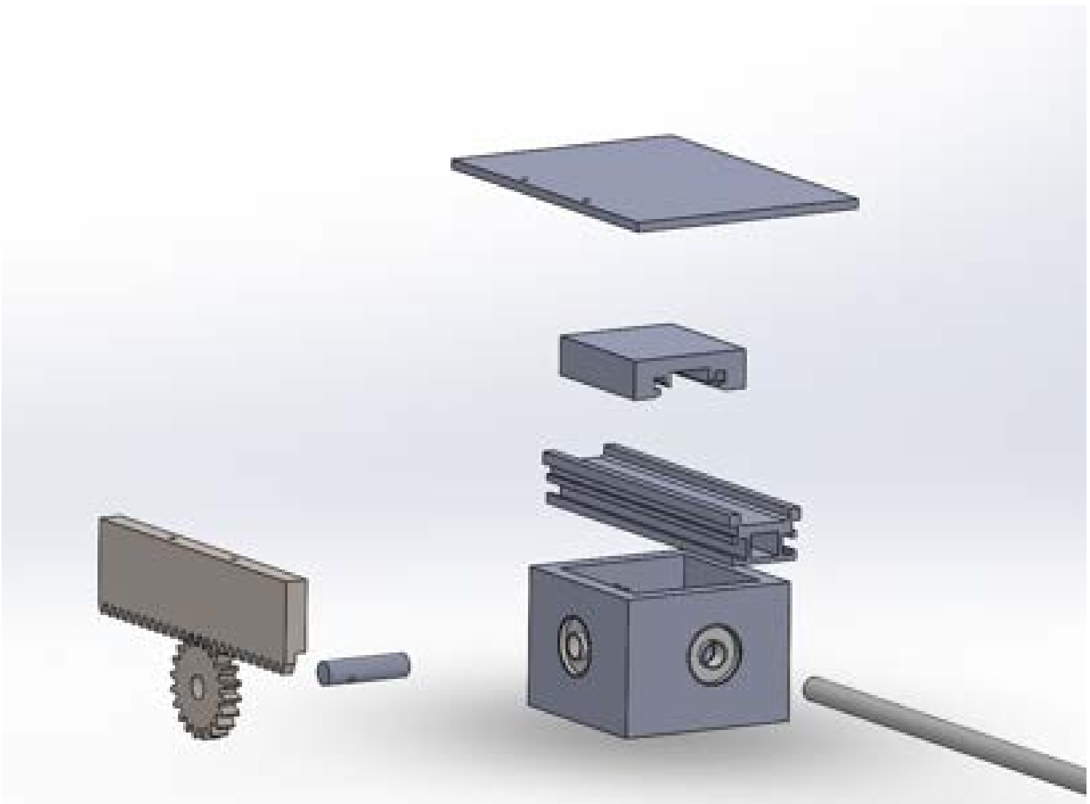


Figure 1: Exploded Full Assembly

This details the parts needed to complete the preliminary design prototype.

The top piece details an initial idea for a phantom base plate to hold phantoms. below it is the slide that was provided to us via our client. The piece the slide slides on is the rail that was also provided to us via our client. Below the slide and rail is the assembled bevel gearbox. To the left of the assembled gearbox is the pin for the pinion. The pin is what connects the bevel gear to the pinion of the rack and pinion. As the bevel gears rotate it will also rotate the pin. The pin has low friction due to the inlaid glass ball bearing. The rotation is then transferred to the rack and pinion which is shown to the left of the pin. As the pinion rotates, its motion is transferred to linear motion to the rack. The rack would be screwed to the phantom base plate via to 3mm screws. As the rack oscillated back and forth in linear motion, so will the phantom linear plate. The Bevel gears are initially rotated by the driveshaft which can be seen in the bottom right of the image.

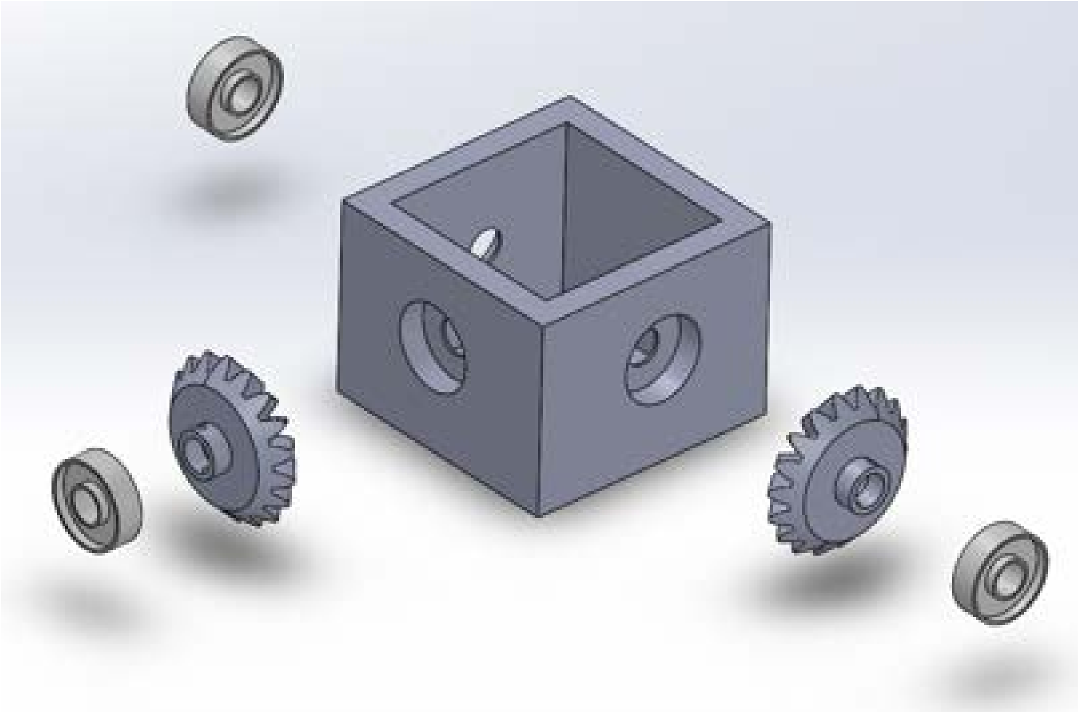


Figure 2: Exploded Bevel Gear Box Assembly

The above image illustrates the exploded view bevel gear box assembly. At the center of the image is the gearbox itself. From where we can see the two bevel gears that sit within the gearbox assembly to the bottom left and right of the box. The glass ball bearings can be seen at the bottom left,right, and top left of the image. These glass ball bearings sit in the inlaid holes of the gearbox assembly. These glass ball bearings allow for minimal resistance for the rotation of the driveshaft to the first bevel gear, and the rotation of the second bevel gear to the pin seen in figure 1.

Conclusions/action items:

MAXWELL NASLUND - Oct 09, 2023, 8:18 PM CDT

Download

GearboxAssem.SLDASM (262 kB)

MAXWELL NASLUND - Oct 09, 2023, 8:18 PM CDT

Download

Full.SLDASM (346 kB)

MAXWELL NASLUND - Oct 09, 2023, 8:20 PM CDT

Download

metric_gear.SLDPRT (252 kB)

MAXWELL NASLUND - Oct 09, 2023, 8:20 PM CDT

Download

Rack.SLDPRT (242 kB)

MAXWELL NASLUND - Oct 09, 2023, 8:20 PM CDT

Download

rail.SLDPRT (151 kB)

MAXWELL NASLUND - Oct 09, 2023, 8:20 PM CDT

Download

slide.SLDPRT (116 kB)

MAXWELL NASLUND - Oct 09, 2023, 8:20 PM CDT

Download

driveshaft.SLDPRT (65.7 kB)

MAXWELL NASLUND - Oct 09, 2023, 8:20 PM CDT

Download

BallBearing.SLDPRT (98 kB)

MAXWELL NASLUND - Oct 09, 2023, 8:20 PM CDT

Download

BevelGear_1.SLDPRT (682 kB)

MAXWELL NASLUND - Oct 09, 2023, 8:20 PM CDT

Download

pin.SLDPRT (93.8 kB)

MAXWELL NASLUND - Oct 09, 2023, 8:20 PM CDT

Download

platform.SLDPRT (77.7 kB)

MAXWELL NASLUND - Oct 09, 2023, 8:20 PM CDT

Download

Motor.SLDPRT (154 kB)

2023/10/11 - Piezoelectric Motor Model

MAXWELL NASLUND - Oct 11, 2023, 10:54 AM CDT

Title: Piezoelectric motor

Date: 2023/10/11

Content by: Maxwell Naslund

Present: N/A

Goals: Detail the solidworks model developed of the piezoelectric motor provided to us by the client

Content:

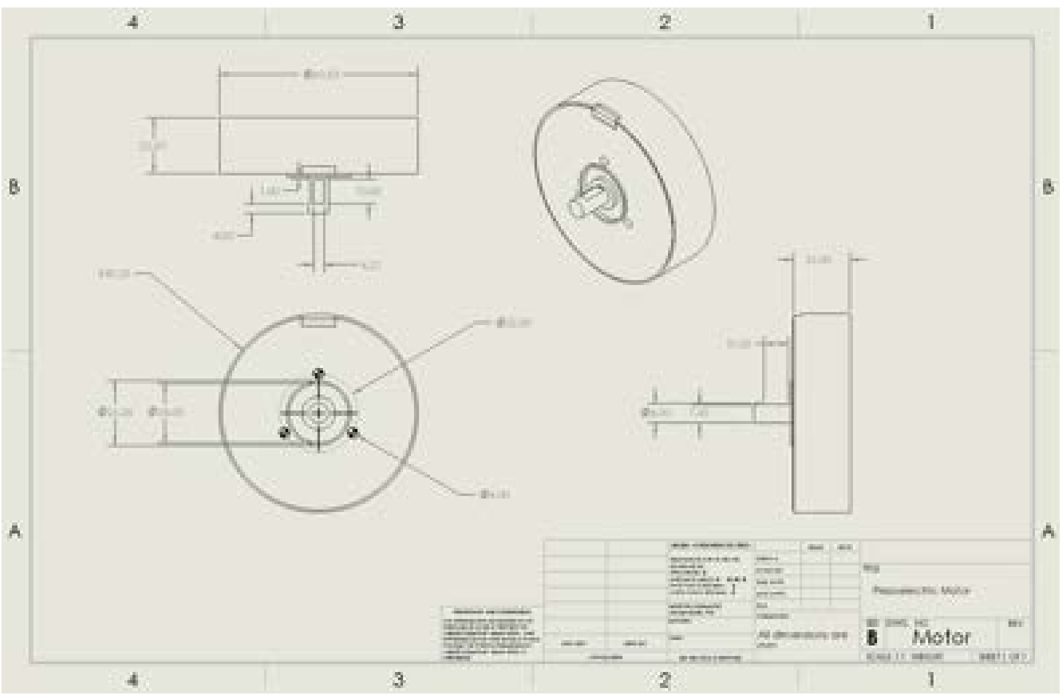


Figure 1: Piezoelectric motor model drawing

Figure 1 above gives detailed dimensions of the piezoelectric motor that the client provided us.

Conclusions/action items:

This SOLIDWORKS model will be helpful with efforts moving forward of modeling our preliminary prototype. It will be very useful in designing future components of energy transfer.

MAXWELL NASLUND - Oct 11, 2023, 10:54 AM CDT

DATA

Download

Motor.SLDDRW (152 kB)

MAXWELL NASLUND - Oct 11, 2023, 10:54 AM CDT

Download

Motor.SLDPRT (175 kB)

2023/10/11 - Linear Rail Model

MAXWELL NASLUND - Oct 11, 2023, 11:04 AM CDT

Title: Linear Rail Model

Date: 2023/10/11

Content by: Maxwell Naslund

Present: N/A

Goals: Detail the dimension used for the solidworks model of the linear rail provided to us by our client

Content:

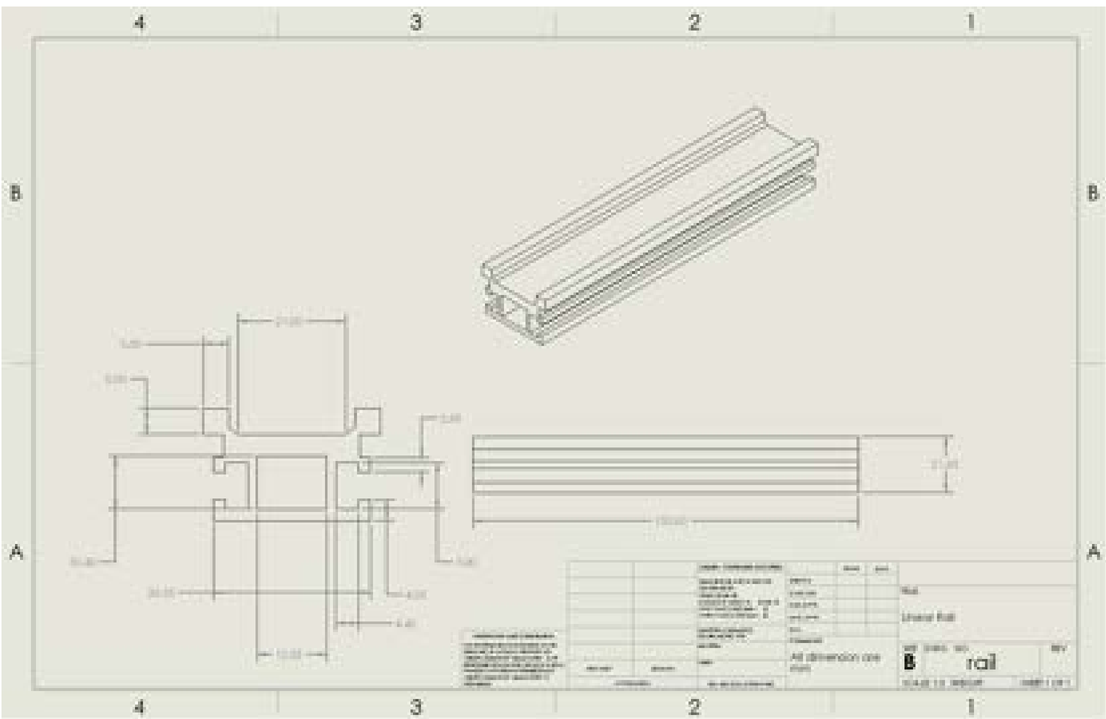


Figure 1: Linear Rail Model

Figure 1 above illustrates in great detail the dimensions of the solidworks model used to represent the linear rail system our client provided us with. This linear rail will be attached to the bevel gear box. On top of these rails, the linear slide can sit, which will be fixed to the phantom bed. This way the phantom bed will be able to oscillate back and forth atop the linear rail.

Conclusions/action items:

This will be useful in further modeling of our preliminary design prototype.

MAXWELL NASLUND - Oct 11, 2023, 11:04 AM CDT

Download

rail.SLDPRT (151 kB)

MAXWELL NASLUND - Oct 11, 2023, 11:04 AM CDT

Download

rail.SLDDRW (110 kB)

2023/10/11 - Linear Slide Model

MAXWELL NASLUND - Oct 11, 2023, 11:10 AM CDT

Title: Linear Slide Model

Date: 2023/10/11

Content by: Maxwell Naslund

Present: N/A

Goals: Detail the dimensions of the linear slide model which represents the linear slide the client provided us to use

Content:

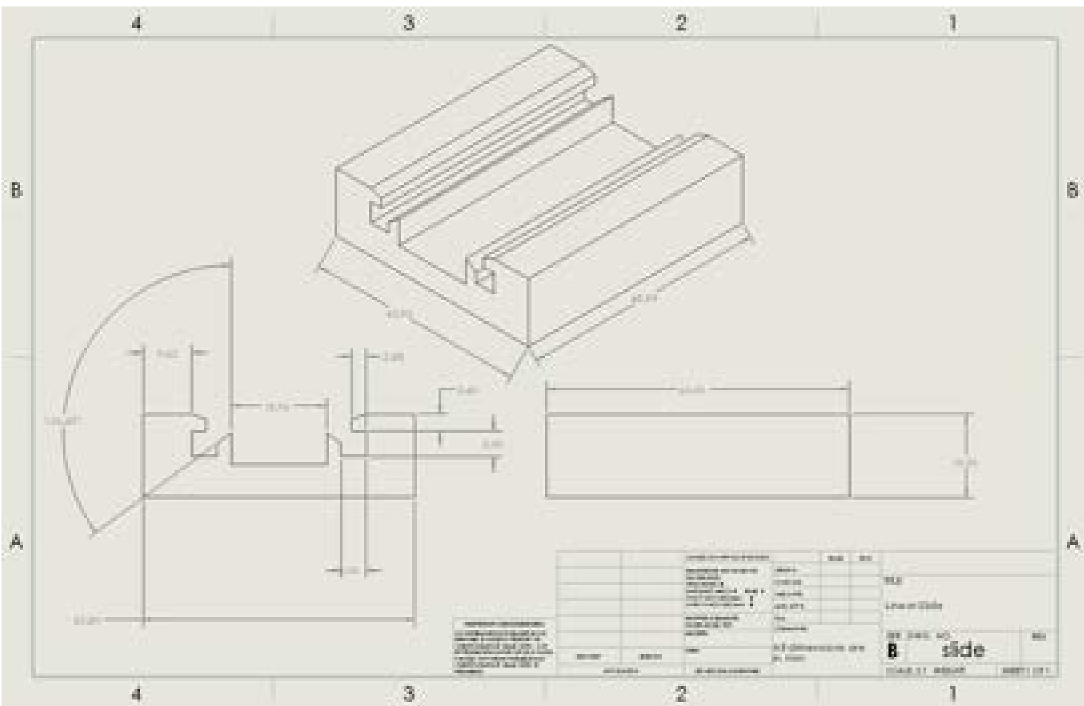


Figure 1: Linear Slide Model

Figure 1 above illustrates in great detail the dimensions of the model used to represent the linear slide the client provided us to use within our project. This will be used in conjunction with the linear rail system. This linear slide will sit atop the linear rail and its movement will be locked in 1-dimension. The phantom bed will be fixed atop this linear slide and will be capable of oscillating back and forth within the 1-dimension.

Conclusions/action items:

This model will be useful in modeling the teams preliminary prototype.

MAXWELL NASLUND - Oct 11, 2023, 11:11 AM CDT

Download

slide.SLDPRT (116 kB)

MAXWELL NASLUND - Oct 11, 2023, 11:11 AM CDT

Download

slide.SLDDRW (115 kB)

2023/10/11 - Pinion Model

MAXWELL NASLUND - Oct 11, 2023, 11:20 AM CDT

Title: Pinion Model

Date: 2023/10/10

Content by: Maxwell Naslund

Present: N/A

Goals: Detail the dimension of the pinion to be used in the rack and pinion system

Content:

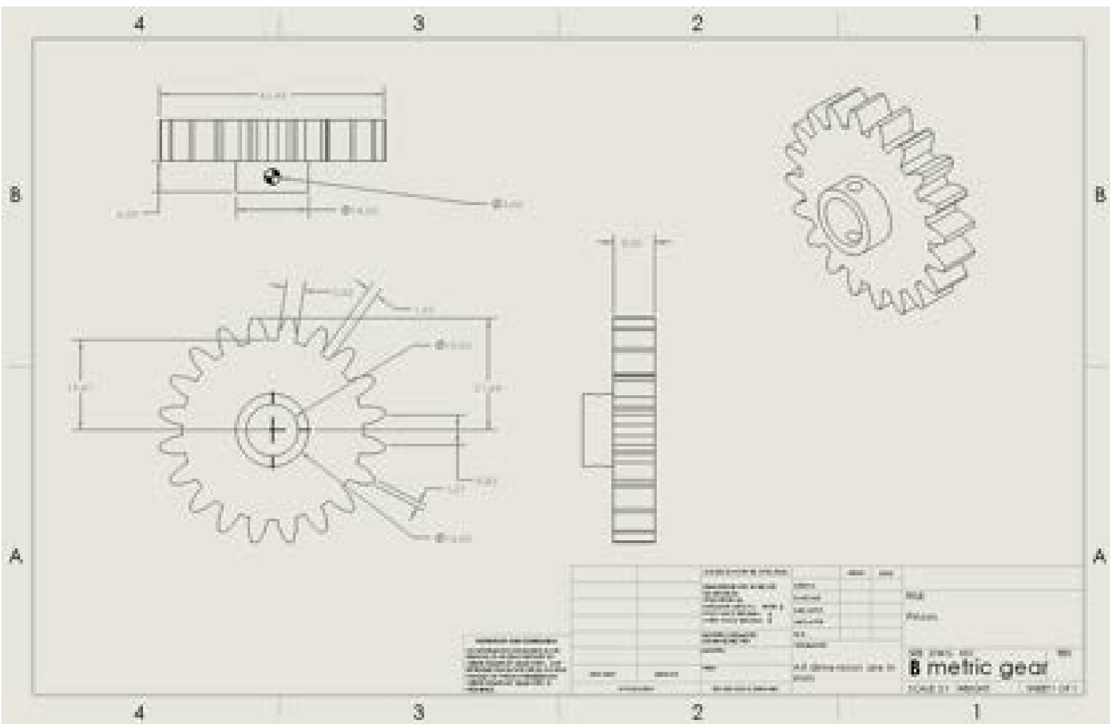


Figure 1: Pinion Model Drawing

Figure 1 above details all the necessary dimensions required to reproduce the pinion gear used to be used in our rack and pinion design. This will take the rotational motion that was been shifted 90 by the bevel gears, and translate it to rack. Once the rotation motion is transferred to the rack, it will become linear motion that can be used to move the phantom bed in whatever oscillations we want.

Conclusions/action items:

This will be useful in designing and modeling our preliminary prototype.

MAXWELL NASLUND - Oct 11, 2023, 11:20 AM CDT

Download

metric_gear.SLDPRT (252 kB)

MAXWELL NASLUND - Oct 11, 2023, 11:20 AM CDT

Download

metric_gear.SLDDRW (204 kB)

2023/10/11 - Rack Model

MAXWELL NASLUND - Oct 11, 2023, 11:28 AM CDT

Title: Rack Model

Date: 2023/10/11

Content by: Maxwell Naslund

Present: N/A

Goals: Detail the dimension of the rack from the rack and pinion system

Content:

Figure 1: Rack Model Drawing

Figure 1 above details the necessary dimensions of the rack from the rack and pinion system. This will take the rotational motion from the pinion and convert it into linear motion. This rack will be attached to the bottom of the phantom bed. As the pinion pushes against this, it will create linear motion and will oscillate back and forth, and hence also oscillate the phantom bed back and forth.

Conclusions/action items:

This will be useful in future modeling of the rack and pinion preliminary design.

MAXWELL NASLUND - Oct 11, 2023, 11:28 AM CDT

Download

Rack.SLDPRT (242 kB)

MAXWELL NASLUND - Oct 11, 2023, 11:28 AM CDT

Download

Rack.SLDDRW (150 kB)

2023/10/27 - PVC Pipe Driveshaft

MAXWELL NASLUND - Oct 27, 2023, 12:29 PM CDT

Title: PCV Pipe Driveshaft

Date: 2023/10/27

Content by: Maxwell Naslund

Present: Jamie, Me

Goals: Outline a potential idea for a driveshaft: PVC Pipe

Link: https://www.grainger.com/product/GF-PIPING-SYSTEMS-Pipe-PVC-5AFJ2

Content:

The link above is for a 10ft PCV pipe that we could potentially use for a driveshaft. We would likely cut this down to a more manageable size. To connect this to the gear box, we would likely 3d print an insert that would fit into the pipe and then fit through the gearbox and then be screwed into the actual gear itself.

Figure 1: 10' 1/2" PCV Pipe

Conclusions/action items:

This would provide us with a cheaper alternative to a ordering a solid rod to use for the design. This would also be easier to access for other labs to assemble their own versions of the device.

2023/12/14 - Gearbox to Driveshaft Adapter

MAXWELL NASLUND - Dec 14, 2023, 8:00 PM CST

Title: Gearbox to Driveshaft Adapter

Date: 2023/12/14

Content by: Maxwell Naslund

Present: n/a

Goals: Outline the design for the gearbox to driveshaft adapter

Content:

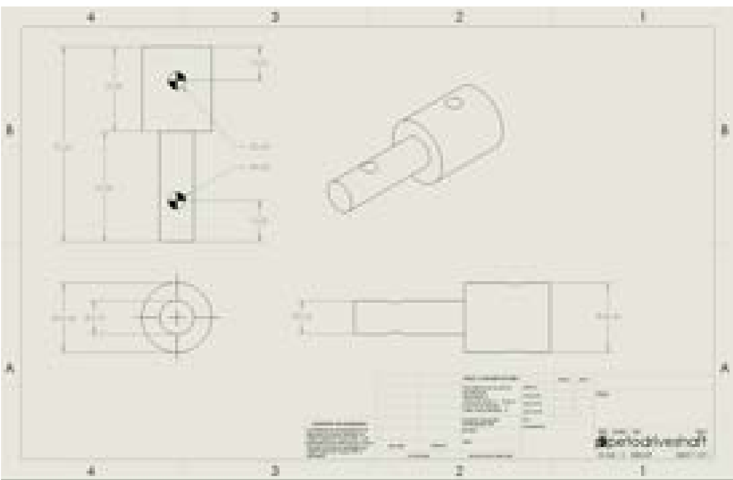


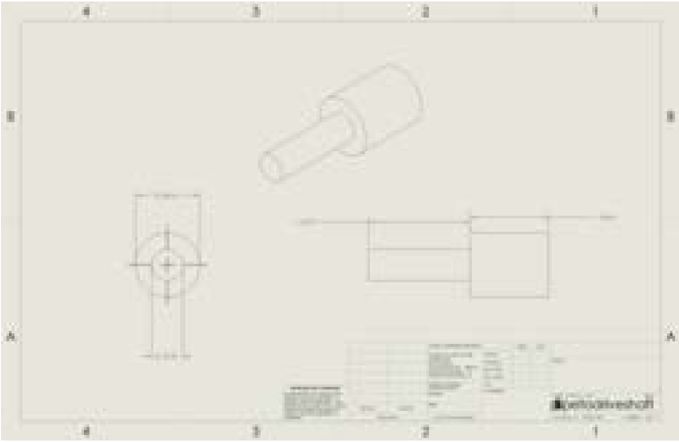
Figure 1: Gearbox to Driveshaft adapter

Figure 1 shows all critical dimensions to create the gearbox to driveshaft adapter. This will be fabricated from HDPE plastic in the TEAM Lab.

Conclusion

This will be used in the final prototype assembly

MAXWELL NASLUND - Dec 14, 2023, 8:01 PM CST



Download

pipetodriveshaft.png (48.1 kB)

MAXWELL NASLUND - Dec 14, 2023, 8:01 PM CST

Download

pipetodriveshaft.SLDDRW (126 kB)

2023/12/14 - Crosspin

MAXWELL NASLUND - Dec 14, 2023, 8:04 PM CST

Title: Crosspin

Date: 2023/12/14

Content by: Maxwell Naslund

Present: n/a

Goals: Outline critical dimensions of the crosspin component of the gearbox

Content:

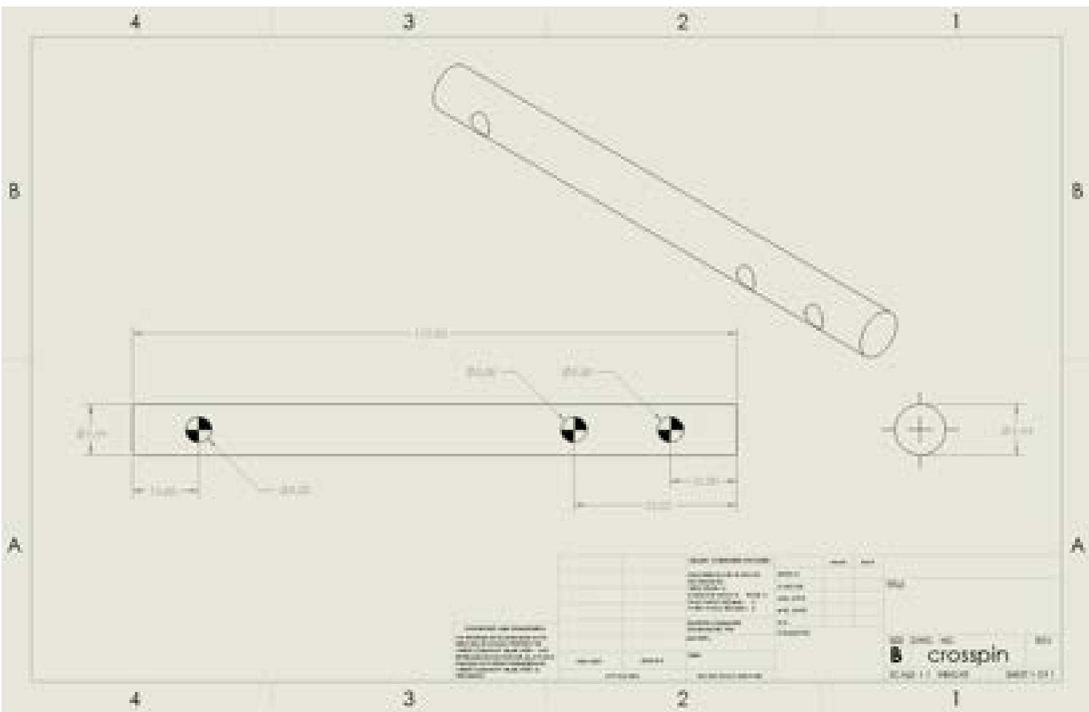


Figure 1: Crosspin

Figure 1 illustrates all critical dimension to create the crosspin component of the final prototype. This will be manufactured from HDPE plastic in the TEAM Lab

Conclusions/action items:

This will be a vital component of the gearbox assembly of the final prototype.

MAXWELL NASLUND - Dec 14, 2023, 8:04 PM CST

[Download](#)

crosspin.SLDDRW (115 kB)

MAXWELL NASLUND - Dec 14, 2023, 8:04 PM CST

Download

crosspin.SLDPRT (137 kB)

2023/12/14 - Motor to Driveshaft Adapter

MAXWELL NASLUND - Dec 14, 2023, 8:08 PM CST

Title: Motor to Driveshaft Adapter

Date: 2023/12/14

Content by: Maxwell Naslund

Present: n/a

Goals: Outline the critical dimensions of the Motor to Driveshaft Adapter

Content:

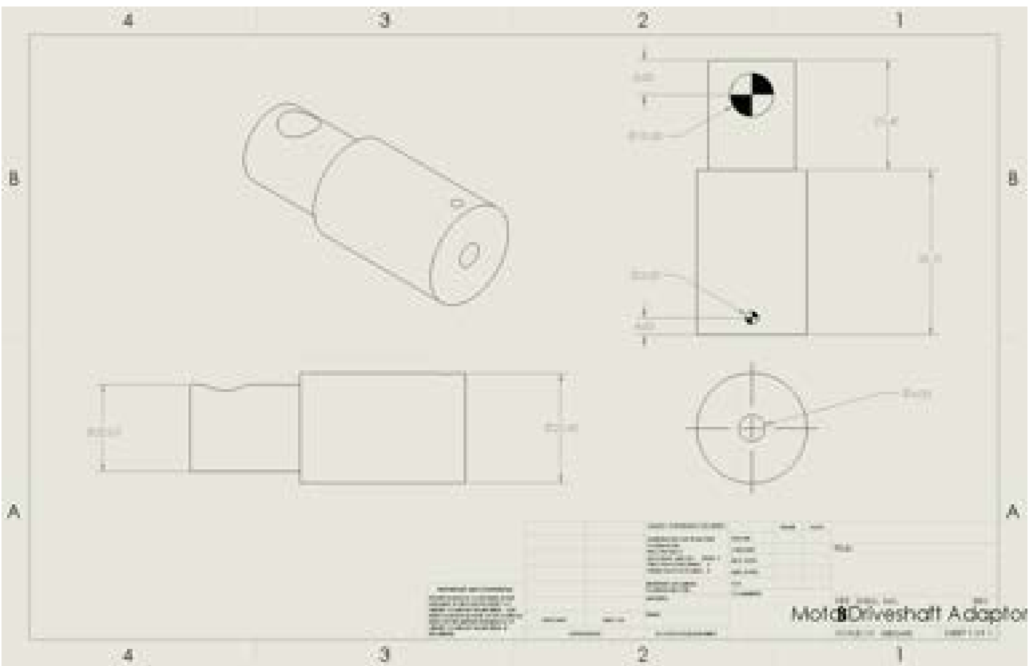


Figure 1: Motor to Driveshaft Adapter drawing

Figure 1 illustrates all critical dimension to create the motor to driveshaft adapter component of the final prototype.

Conclusions/action items:

This will be a vital component of the motor assembly of the final prototype. This will be fabricated in the TEAM Lab from 1" aluminum stock.

MAXWELL NASLUND - Dec 14, 2023, 8:08 PM CST

Download

MotorDriveshaft_Adaptor.SLDDRW (126 kB)

MAXWELL NASLUND - Dec 14, 2023, 8:08 PM CST

Download

MotorDriveshaft_Adaptor.SLDPRT (155 kB)

2023/12/14 - Phantom Bed Updated

MAXWELL NASLUND - Dec 14, 2023, 8:12 PM CST

Title: Phantom Bed Updated

Date: 2023/12/14

Content by: Maxwell Naslund

Present: n/a

Goals: Outline critical dimensions of the Phantom Bed

Content:

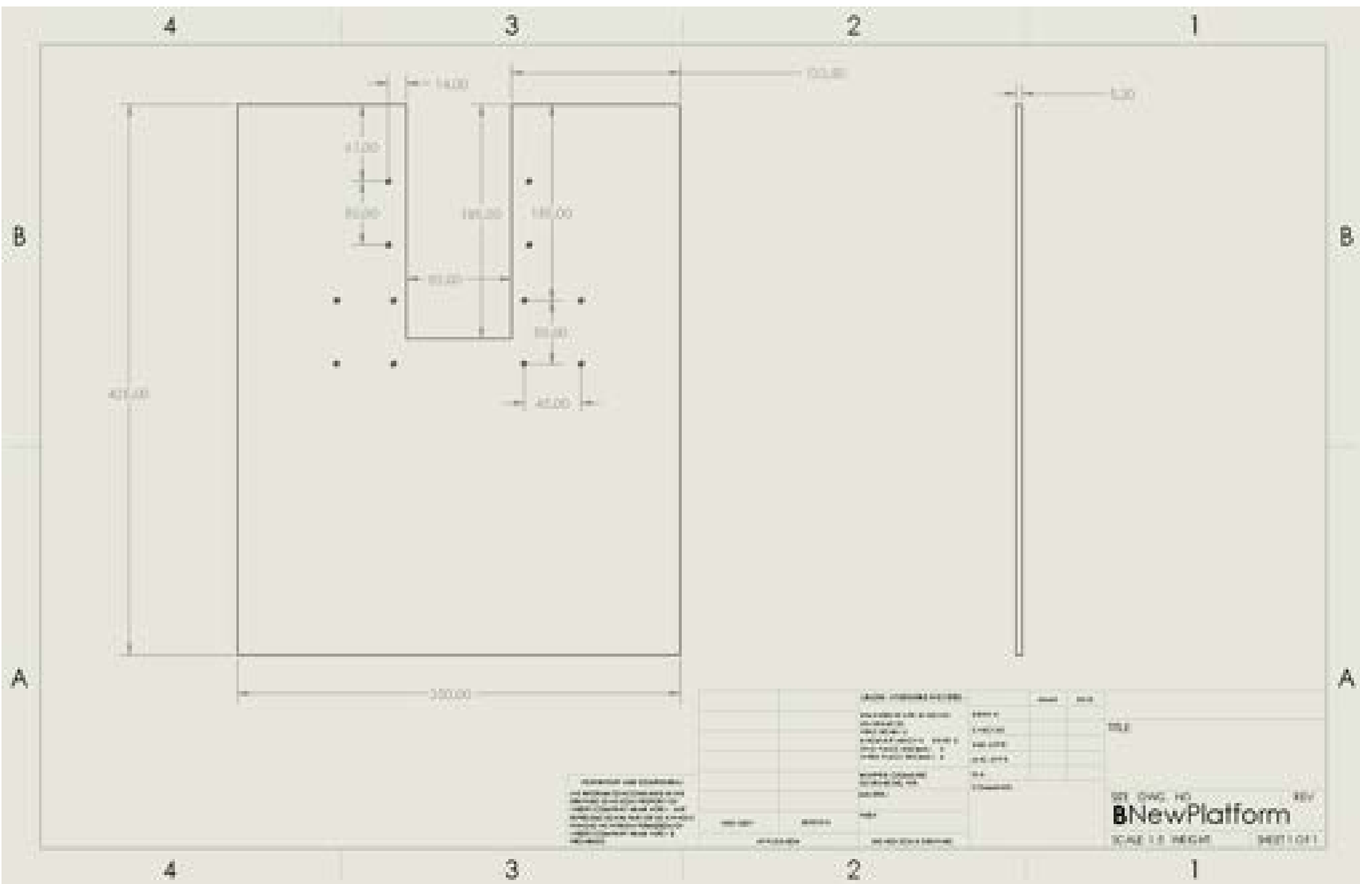


Figure 1: Phantom Bed Drawing

Figure 1 illustrates all critical dimensions to create the phantom bed component of the gearbox assembly.

Conclusions/action items:

This will be a vital component of the gearbox assembly in the final prototype. This will be fabricated from acrylic to be MR compatible.

MAXWELL NASLUND - Dec 14, 2023, 8:12 PM CST

Download

NewPlatform.SLDDRW (115 kB)

MAXWELL NASLUND - Dec 14, 2023, 8:12 PM CST

Download

NewPlatform.SLDPRT (125 kB)

MRI

CASPAR UY - Oct 11, 2023, 4:43 PM CDT

Name: MRI (Magnetic Resonance Imaging)

Present: Caspar Uy

Date: 9-8-2023

URL: https://my.clevelandclinic.org/health/diagnostics/4876-magnetic-resonance-imaging-mri

Search Term: MRI practices

Citation: Cleveland Clinic medical. “MRI (Magnetic Resonance Imaging): What It Is, Types & Results.” Cleveland Clinic, my.clevelandclinic.org/health/diagnostics/4876-magnetic-resonance-imaging-mri. Accessed 9 Sept. 2023.

Goals: Understand the process of how MRIs work

Content: MRIs are designed to create clear images of the structures within biological subjects through the use of a large magnet, radio waves and a computer. The data is then used to help evaluate, diagnose, and monitor the status of the subject.

Parts MRIs can show: “

-
- Your brain and surrounding nerve tissue.
- Organs in your chest and abdomen, including your heart, liver, biliary tract, kidneys, spleen, bowel, pancreas and adrenal glands.
- Breast tissue.
- Your spine and spinal cord.
- Pelvic organs, including your bladder and reproductive organs (uterus and ovaries in people assigned female at birth and the prostate gland in people assigned male at birth).

“

Conclusion/Actions: Continue to research on MRI standards and practices.

Materials - PLA

CASPAR UY - Oct 11, 2023, 4:43 PM CDT

Name: What is PLA?

Present: Caspar Uy

Date: 9-22-2023

URL: https://www.twi-global.com/technical-knowledge/faqs/what-is-pla#Advantages

Search Term: PLA properties

Citation: “What Is Pla? (Everything You Need to Know).” TWI, www.twi-global.com/technical-knowledge/faqs/what-is-pla#Advantages. Accessed 22 Sept. 2023.

Goals: Have the data and other listed applications for PLA

Content: PLA is polylactic acid, a thermoplastic monomer. It is generally easy to print and when disposed of properly environmentally friendly.

PLA properties: “

Property	Value
Heat Deflection Temperature (HDT)	126 °F (52 °C)
Density	1.24 g/cm³
Tensile Strength	50 MPa
Flexural Strength	80 MPa
Impact Strength (Unnotched) IZOD (J/m)	96.1
Shrink Rate	0.37-0.41% (0.0037-0.0041 in/in

“

Conclusion/Actions: Research other MR compatible materials that will not interfere the client’s experimental MRI

Methods - Injection Molding

CASPAR UY - Oct 11, 2023, 4:46 PM CDT

Name: Processing Guide:Injection Molding of Standard and High heat PLA compounds

Present: Caspar Uy

Date: 9-29-2023

URL: https://www.totalenergies-corbion.com/media/ny1kwp02/processing-guide-injection-molding-of-standard-and-high-heat-pla-compounds-20220722.pdf

Search Term: Injection Molding process

Citation: Processing Guide - Totalenergies Corbion. (n.d.). https://www.totalenergies-corbion.com/media/ny1kwp02/processing-guide-injection-molding-of-standard-and-high-heat-pla-compounds-20220722.pdf

Goals: Determine the feasibility of injection molding compared to 3D printing.

Content: Injection molding involves melting the PLA and under high pressure injected into a mold. Similar to how wax figures are quickly made for souvenirs. Difference is the mold is generally filled with the PLA rather than filled with air.

Process of using an injection molding set up:

"

Before introducing Luminy® PLA, the injection molding machine needs to be well cleaned and purged to prevent cross contamination. Also, make sure that the feeding and blending equipment in the material preparation steps (before the materials and additives enter the extruder) is extensively cleaned and that they are free of dust and contamination. The injection molding machine purging procedures below are recommended for removing other polymers when processing PLA.

1. Check if other polymers from previous runs are present in the barrel of the machine. To prevent starting up the machine with non- molten material, the temperature range of the machine should be set to the processing temperature of the previously used polymer or the PLA, whichever has the highest processing temperature.

2. Purge the system with a polyolefin with similar MFI to PLA, or a purging compound (e.g. ASAclean, Dyna-Purge, etc.) followed by purging with the PLA homopolymer.

3. Change the temperature of the barrel to the required temperature for PLA.

4. Check that the processed material is free of contamination before starting production.

5. At completion of the run, it is recommended to purge the system again by using a purging compound to clean the machine from

remaining PLA material. Check the recommendations of the supplier of the purging material for the right conditions.

"

Conclusion/Actions: After speaking with Advisor and rest of team injection molding would not be feasible given costs and resources.

MRI standard

CASPAR UY - Oct 11, 2023, 4:41 PM CDT

Name: MRI Information for Industry

Present: Caspar Uy

Date: 9-8-2023

URL: https://www.fda.gov/radiation-emitting-products/mri-magnetic-resonance-imaging/mri-information-industry

Search Term: MRI standards

Citation: Center for Devices and Radiological Health. “MRI Information for Industry.” U.S. Food and Drug Administration, FDA, www.fda.gov/radiation-emitting-products/mri-magnetic-resonance-imaging/mri-information-industry. Accessed 8 Sept. 2023.

Goals: Find and learn of current US MRI standards

Content: Contains lists of individual standards about different processes and setups for varying MR-compatible machines. Since MRIs are medical devices and radiation-emitting electronics, in America, they follow requirements under the FDA and are identified as Class II medical devices.

Standards Relevant to MRIs: “

- IEC 60601-2-33 - Medical Electrical equipment – Part 2-33: Particular requirements for the basic safety and essential performance of magnetic resonance equipment for medical diagnosis
- EC 62464-1 - Magnetic resonance equipment for medical imaging Part 1: Determination of essential image quality parameters.
- NEMA MS 1 - Determination of Signal-to-Noise Ratio (SNR) in Diagnostic Magnetic Resonance Images
- NEMA MS 2 - Determination of Two-dimensional Geometric Distortion in Diagnostic Magnetic Resonance Images
- NEMA MS 3 - Determination of Image Uniformity in Diagnostic Magnetic Resonance Images
- NEMA MS 4 - Acoustic Noise Measurement Procedure for Diagnostic Magnetic Resonance Imaging Devices
- NEMA MS 5 - Determination of Slice Thickness in Diagnostic Magnetic Resonance Imaging
- NEMA MS 6 - Determination of Signal-to-Noise Ratio and Image Uniformity for Single-Channel, Non-Volume Coils in Diagnostic Magnetic Resonance Imaging (MRI)
- NEMA MS 8 - Characterization of the Specific Absorption Rate for Magnetic Resonance Imaging Systems
- NEMA MS 9 - Characterization of Phased Array Coils for Diagnostic Magnetic Resonance Images
- NEMA MS 10 - Determination of Local Specific Absorption Rate (SAR) in Diagnostic Magnetic Resonance Imaging Systems
- NEMA MS 12 - Quantification and Mapping of Geometric Distortion for Special Applications
- NEMA MS 14 - Characterization of Radiofrequency (RF) Coil Heating in Magnetic Resonance Imaging Systems

“

Conclusion/Actions: Learn more about the individual standards to apply towards what the client requires.

Magnetic Safety Test - Standard

CASPAR UY - Oct 11, 2023, 4:42 PM CDT

Name: ASTM F2052 Standard Test Method for Measurement of Magnetically Induced Displacement Force on Medical Devices in the Magnetic Resonance Environment.

Present: Caspar Uy

Date: 9-9-2023

URL: https://www.astm.org/f2052-21.html

Search Term: ASTM F20252 Standard Test Method MRI

Citation: "Standard Test Method for Measurement of Magnetically Induced Displacement Force on Medical Devices in the Magnetic Resonance Environment." F2052, www.astm.org/f2052-21.html. Accessed 9 Sept. 2023.

Goals: Learn more about the process for using and safely operating an MRI based on Standards.

Content:

This specific standard is designed to assess the safety of MR medical device as to its ability in causing malignant effects on the subject in use of the device. The tests focus primarily on measuring the magnetic fields within and around the device.

Limitations of the test: "

5.4 This test method alone is not sufficient for determining if a device is safe in the MR environment

…

This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.

"

Conclusion/Actions: Meet with team and discuss more test successful materials.

Rack & Pinion Railway

CASPAR UY - Oct 11, 2023, 6:16 PM CDT

Name: Rack and Pinion Rail

Present: Caspar Uy

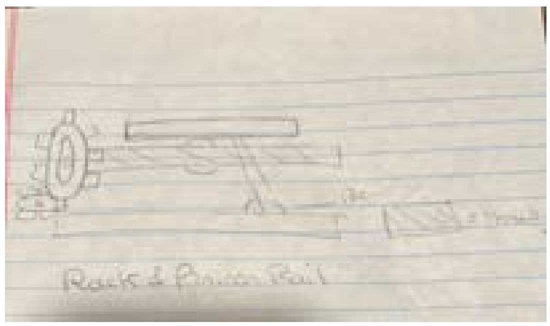
Date: 10-11-2023

Goal: Document initial idea for design

Content: The design involved a rack and pinion as the main function but included a threaded pole for the platform to move with while supported by a bearing roller that would supposedly allow for smoother travel.

Conclusion: It would be too costly plus the rack and pinion on its own would suffice.

CASPAR UY - Oct 11, 2023, 6:16 PM CDT



Download

R_P_Rail.jpg (16.4 kB)

Load Test

CASPAR UY - Dec 14, 2023, 6:31 PM CST

Name: Load Variance Test Draft

Present: Whole Team

Date: 11-17-2023

Purpose: This test is designed to assess the performance of the prototype in carrying different loads. A set weight will be placed on the platform and will be recorded on video for at least 10 trials for each weight. Once at least 10 trials for a weight have been completed the next increment of weight will be placed on the platform until the maximum load specified by the client is reached. Each video will be compared to a video of the prototype carrying no load.

Content:

1. Measure and record the mass of the platform
2. Set-up camera to have full view of the platform distance
3. Start video recording
4. Place specified mass on platform
5. Turn on motor
6. Record time
7. Repeat 3-6 until 10 trials have been achieved for the specified mass
8. Repeat 3-7 until all specified masses have been tested.
9. In Kinovea upload the video files and mark components of interest to determine the efficiency of the motor

Conclusion: Work with team on completing it.

Code - Functionality Test

CASPAR UY - Dec 14, 2023, 6:31 PM CST

Name: Code and Functionality Test

Present: Whole Team

Date: 11-17-2023

Purpose: The first test is designed to assess component proficiency, specifically the movement of gears and teeth needed to optimally move the platform. This test will be conducted without additional weight. There will be at least 10 trials measuring the amount of rotations and the full time to travel the track. The data will be compared against each other.

Content:

1. Measure and record the mass of the platform
2. Set-up cameras near the bearings and motor and record
3. With the code, activate the motor
4. Record a video of the rotations
    1. Record number of rotations over time
    2. Record total time
5. Repeat 3-4 until 10 trials have been conducted

Conclusion: Show to Amber and Kendra to conduct given they have a functional mBed

Velocity Variance Test

CASPAR UY - Dec 14, 2023, 6:30 PM CST

Name: Velocity Variance Test

Present: Whole Team

Date: 11-17-2023

Purpose: At programmed speeds the prototype will be assessed to how accurate the physical speed is compared to the expected speed. At least 10 trials will be conducted for each set speed. The load will be constant throughout the trials.

Content:

1. Set the load to 0 additional load, mass of just the platform
2. Upload the specified variance speed from the code
3. Set-up camera in full view of the platform and record video
4. Once a full cycle is complete stop recording the video
5. Record total time to complete the cycle at set speed compared to actual speed
6. Repeat 1-5 until 10 trials of the specified speed is achieved
7. Repeat 1-6 until all specified speeds are achieved

Conclusion: Update with team

Safety Test

CASPAR UY - Dec 14, 2023, 6:31 PM CST

Name: Safety Test

Present: Whole Team

Date: 11-17-2023

Purpose: This test is to determine safety values within the prototype. For example, determining the temperatures collected during standard run times.

Content:

Temperature Test - Designed to assess the potential of any overheating or dangerous to touch temperature levels

1. With no additional load set-up platform
2. Set-up camera in full view of platform space and in line of sight of the temperature gun
3. Record video
4. Run the motor for a full cycle
5. At specified points during the cycle measure and record the temperature and the time
6. Stop video recording once full cycle is complete
7. Repeat steps 1-6 until 10 trials have been achieved.
8. Repeat steps 2-6 until 10 trials have been achieved with the maximum specified mass.

Conclusion: Update with Team

12-8-2023: Suggestions from Client

CASPAR UY - Dec 14, 2023, 6:42 PM CST

Title: Suggestions from Client from Poster Presentations

Present: All team members

Date: 12-8-2023

Content:

Client is happy with the effort and overall design of the prototype. One of the suggestions given was if metallic screws were necessary to move forward acquire and test brass screws. Additionally, they suggested to modify the prototype so it can last longer than 1 minute, ideally 15 minutes given the criteria.

Another suggestion not from the client was to reaffirm the MR safety over MR compatible since MR safe will allow for more universal use.

Conclusion: Conduct further research on modifying the code and brass properties.

2023/9/14- The need for meterology

Kendra Besser - Oct 02, 2023, 4:54 PM CDT

Title: The need for Meterology

Date: 9/15/23

Content by: Kendra

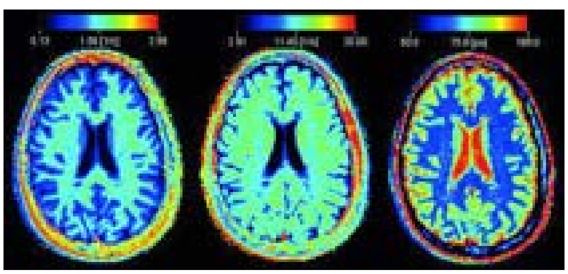
Present: Kendra

Goals: Have a clear understanding of what quantitative MRI is.

Content:

Citation: Cashmore, M. T., McCann, A. J., Wastling, S. J., McGrath, C., Thornton, J., & Hall, M. G. (2021). Clinical quantitative MRI and the need for metrology. The British journal of radiology, 94(1120), 20201215. https://doi.org/10.1259/bjr.20201215

- There is a strong need for quantitative and measurable MRI studying
- most MRI used today are qualitative and need someone to look over the imaging in order to determine a problem or measure a mass
- quantitative MRI will give values and definitive answers that eliminate human error
- qMRI can scan for things like tissue volume, composition, and microstructure
- qMRIs provide a calibration between different rounds of imaging
    - this is especially helpful in large clinical trials
    - gives each patients readings equal opportunity
- quantitative results uncertainty is very difficult to define in qMRI as of today, which can skew the results



Conclusions/action items:

Quantitative MRIs are arising in medical technology. This technique is different from the typical MRI because it defines exact measurements of various characteristics of tissue that can be extremally supportive to a diagnosis.

2023/9/14-Motion Robust qMRI

Kendra Besser - Sep 15, 2023, 11:09 AM CDT

Title: quantitative MRI

Date: 9/14/23

Content by: Kendra

Present: Kendra

Goals: Understand why qMRI needs to be motion robust and how it can achieve that.

Content:

Geng, R., Zhang, Y., Rice, J., Muehler, M. R., Starekova, J., Rutkowski, D. R., Uboha, N. V., Pirasteh, A., Roldán-Alzate, A., Guidon, A., & Hernando, D. (2023). Motion-robust, blood-suppressed, reduced-distortion diffusion MRI of the liver. *Magnetic resonance in medicine*, *89*(3), 908–921. https://doi.org/10.1002/mrm.29531

- this study used a liver phantom with controlled pulsation
- Standard monopolar and motion-robust (M1-nulled, and M1-optimized) DW gradient waveforms were
  - controlled waveforms were generated for the motion
- results:
  - SD motion affected results greatly
  - results were more skewed in older patients
    - could be from more damaged liver?
    - harder to scan?

Conclusions/action items:

Quantitative MRIs were used in a study to test liver disease. A standard waveform was used to see if it affected the results. The motion did skew results.

2023/9/15-MR compatibiity

Kendra Besser - Sep 15, 2023, 11:

Title: MR Compatibility

Date: 9/14/23

Content by: Kendra

Present: Kendra

Goals: Understand what makes a material MR compatible.

Content:

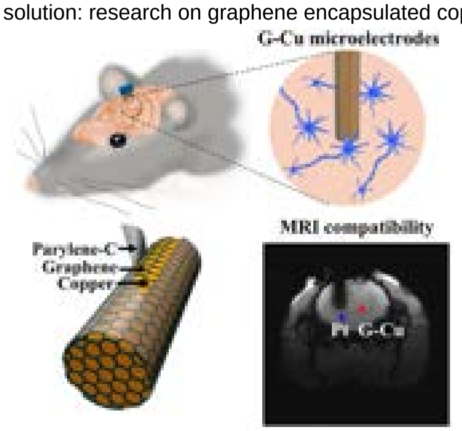
link: https://blog.sliceproducts.com/blog/mri-compatible#:~:text=MRI%2DCompatible%20Metals%3A%20The%20Breakdown,Aluminum

- MR safe
  - nonmagnetic (nonferrous or nonferromagnetic)
- examples
  - Titanium
  - Aluminum
  - Brass
  - Copper
  - Bronze
  - Aluminum Bronze Alloy
- titanium
  - the most common material used for MRI tools
  - lightweight, strong, nonmagnetic
  - very expensive (adjustable wrench is $300-$500), aluminum bronze alloy also expensive (wrench $200-$300)
- non-metal MRI safe
  - examples: glass, nylon, Teflon, and various plastics
  - blade material: ceramics
  - most tools that feature glass-infused handles and nonferrous fasteners and springs are MRI compatible

link: https://pubs.acs.org/doi/10.1021/acs.nanolett.6b03829#:~:text=Copper%20is%20a%20favorable%20material,direct%20implantation%20for%20neural%20r

link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3655294/

- non magnetic metals that are still harmful
  - copper
    - good because has magnetic susceptibility close to water and tissues
      - little to no magnetic pull
    - the cytotoxicity of copper precludes its direct implantation for neural recording
      - damaging cells around it (toxic)
    - solution: research on graphene encapsulated copper (G-Cu) microelectrode



Conclusions/action items:

for this project we will stick to nonmagnetic metals or nonmetals as our primary materias.

2023/10/1 - qMRI vs MRI

Kendra Besser - Oct 11, 2023, 2:30 PM CDT

Title: qMRI vs MRI

Date: 10/1/23

Content by: Kendra

Present: Kendra

Goals: Understand the difference between qMRI and MRI

Content:

Source: https://www.diva-portal.org/smash/get/diva2:686108/FULLTEXT01.pdf

- Magnetic resonance imaging (MRI) is a sensitive technique for assessing white matter (WM) lesions in multiple sclerosis (MS)
- there is a low correlation between MRI findings and clinical disability

qMRI

- In contrast to conventional MRI, quantitative MRI (qMRI) is aimed at the direct measurement of the physical tissue properties
- measurement of the physical tissue properties, such as the relaxation times, T1 and T2, as well as the proton density (PD)
- promising for characterizing and quantifying changes in MS and for brain tissue segmentation
- developed methods were validated in control subjects and MR phantoms
- able to detect and quantify changes in the MS disease that were not visible using conventional MRI
- could be used for brain tissue segmentation and volume estimation of the whole brain, using pre-defined tissue characteristics

Conclusions/action items:

qMRI is a developing MRI technique that if it can be developed robustly, can lead to a whole new field of diagnostics. qMRIs have the ability to detect diseases and disorders before they show physical characterizes in patients. qMRIs can be used in a number of fields including liver, brain, tendon, and many more.

2023/10/2- qMRI definition

Kendra Besser - Oct 02, 2023, 6:37 PM CDT

Title: qMRI definition

Date: 10/2/23

Content by: Kendra

Present: Kendra

Goals: Define qMRI and what it can be used for

Content:

Source: https://hai.stanford.edu/news/broadening-use-quantitative-mri-new-approach-diagnostics - Dec 2021

What is qMRI

- a new variation of MRI/ emerging field
- captures valuable non-visual metrics of the chemical structure and makeup of tissues
- reveals even more information/insight into the cases being imaged
- SKM-TEA is a database used to train AI to make qMRIs quicker and more detailed which will help clinics access qMRIs

Source: https://www.sciencedirect.com/science/article/pii/B9780128170571000019

rational for qMRI and challenges

- The range of properties that have been accessed with MRI includes the nuclear magnetic resonance (NMR) relaxation times T1 and T2, diffusion, perfusion, fat and water fractions, iron fraction, elastic properties of tissue, temperature, chemical composition, and chemical exchange
- the intensity of each pixel corresponds to a measurement of one specific physical or physiological property

Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6663309/

- phantoms, protocol, and software should be developed with the challenges of the particular anatomical motion considered
- The phantoms and test methods need to be transferred into the clinic, such that reliable and reproducible qMRI becomes routine
- Then, the value of qMRI can make a definitive impact

Conclusions/action items:

Quantitative MRI is an emerging field measures physiological measurements in an MR image and maps the corresponding values to the image. consistency is protocols and softwares are not sufficient enough to allow qMRI methods to be used in clinics.

2023/12/13- breath-hold artifacts

Kendra Besser - Dec 13, 2023, 8:13 PM CST

Title: breath hold artifacts

Date: 12/13/23

Content by: Kendra

Present: Kendra

Goals: Understand the breath holding procedure and the implications on MRIs when not breath holding.

Content:

Source: https://pubmed.ncbi.nlm.nih.gov/8598819/

Citation: D. A. Feinberg, N. M. Rofsky, and G. Johnson, “Multiple breath-hold averaging (mba) method for increased snr in abdominal mri,” Magn. Reson. Med., vol. 34, no. 6, pp. 905–909, 1995, doi: 10.1002/mrm.1910340617.

notes:

- Breath-holding during MR imaging eliminates respiratory motion artifacts
- major time constraint on data acquisition
- limits image signal-to-noise ratio (increases noisiness) and hence limits spatial resolution (resolution/quality of image)
    - Signal to Noise Ratio (SNR) is a measure of the image signal in an area of tissue with respect to the background tissue
    - is a measure of true signal (i.e. reflecting actual anatomy) to noise (e.g. random quantum mottle)
    - a lower signal-to-noise ratio generally results in a grainy appearance to images
    - the higher the ratio, the better the signal quality
- multiple breath-hold averaging
    - another technique to eliminate the error of short data acquisition time
    - however does not elevate the need to hold your breath
    - takes multiple trials and averages the MRI data to one result

Conclusions/action items:

Quantitative MRI is an emerging field measures physiological measurements in an MR image and maps the corresponding values to the image. consistency is protocols and softwares are not sufficient enough to allow qMRI methods to be used in clinics.

2023/9/27 - QUASAR

Kendra Besser - Oct 11, 2023, 2:44 PM CDT

Title: QUASAR

Date: 9/27/23

Content by: Kendra

Present: Kendra

Goals: document the competitive design QUASAR.

Content:

Source: https://modusqa.com/products/quasar-mri4d-motion-phantom/#:~:text=Quasar%20MRI%E2%81%B4%E1%B4%B0%20is%20the,%2Dsim%20and%20MR%2DLinacs.

- only uses one size test tube - you cant use your own phantom products
- motor very close to sampling product (can skew image)
- specs: https://modusqa.com/wp-content/uploads/2020/02/Modus-QA-Product-Data-Sheet-MRI4D.pdf
- world's first MR-safe programmable motion phantom
- Interchangeable inserts are available for imaging
- included software provides tools to create, import, edit and stream patient-specific respiratory waveforms

software

- intuitive programmable respiratory motion QA software
- customization of motion waveforms
- incorporated Deep Inspiration Breath Hold Function increases workflow efficiency for users to test DIBH protocols
- Latency Data Reporting

Conclusions/action items:

The QUASAR design is a similar idea to what we want to build, however, there are some major downfalls to this designs. Those downfalls include only being able to produce respitory motion, having the phantom to be the size of the gven test tube, and having the motor too close to the phantom (can mess with the results).

2023/9/27 - Research Study

Kendra Besser - Oct 11, 2023, 3:02 PM CDT

Title: QUASAR

Date: 9/27/23

Content by: Kendra

Present: Kendra

Goals: document the competitive design studied in the research report.

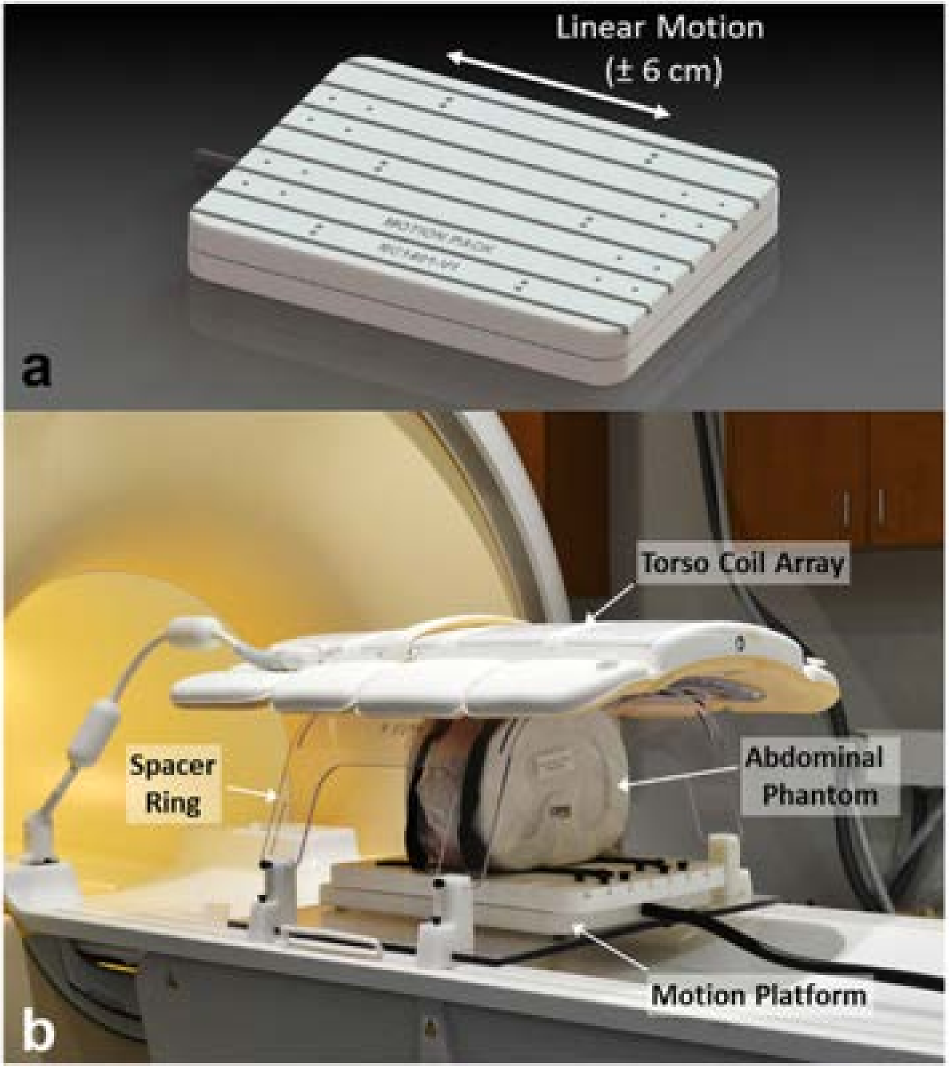
Content:

Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6342555/

- specs: file:///C:/Users/Owner/Downloads/NIHMS994640-supplement-SUPPORTING_INFORMATION.pdf
- information sheet: https://cds.ismrm.org/protected/15MProceedings/PDFfiles/1629.pdf

overview:

- The goal of this study was to evaluate a programmable system for one-dimensional motion management MRI research
- programmable motorized linear stage and computer was assembled and tested in the MRI environment
- Tests of the mutual interference between the platform and a whole-body MRI were performed
- No interference between the motion platform and the MRI was observed
- T2 measurement of a kidney lesion in an abdominal phantom showed that its value decreased by 67% with physiologic motion, but could be partially recovered with navigator-based motion-compensation



methods

- The motion platform is composed of two parts: a motorized linear stage located inside the bore of the MRI, and driving electronics located at the operator suite
- three nonmagnetic linear bearing slides
- was driven with two nonmagnetic piezoceramic motors
- An optical encoder was used to provide position information
- structure consisted of a large flat surface that could be translated in a linear fashion along one direction
- detail of the fabrication https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6342555/#SD1

Conclusions/action items:

This qmri platform design is a good idea however it is difficult to reproduce and very expensive to buy. the motor is also very close to the platform which can hinder results.

2023/10/11 - Rack and pinion

Kendra Besser - Oct 11, 2023, 3:13 PM CDT

Title: Rack and pinion design

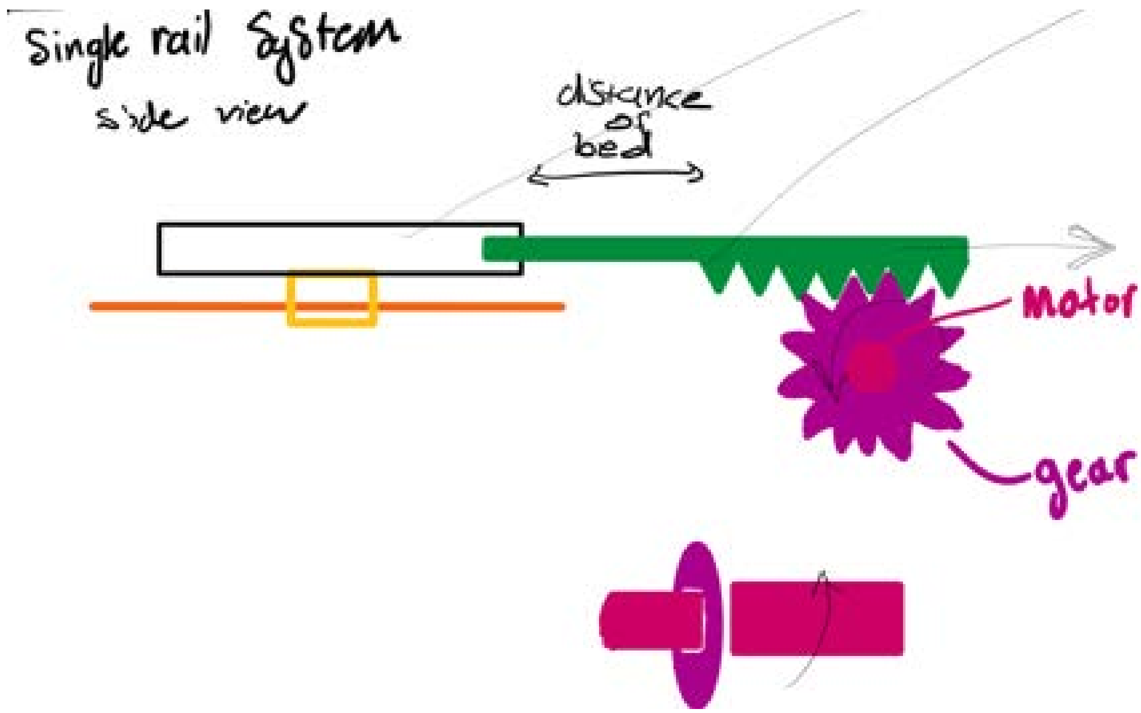
Date: 10/11

Content by: Kendra

Present: Kendra

Goals: To document the design idea I came up with and shared with the group

Content:



This design uses a rack and pinion design to translate the rotational motion to linear motion. There is a side view of the motor to show how the gear will be situated to the motor axial.

Conclusions/action items:

This design is similar to Ambers design; however, my rack and pinion design extends all the way to the motor so there is no need for beveled gears.

2023/10/11 - Rail ideas

Kendra Besser - Oct 11, 2023, 3:16 PM CDT

Title: Rail ideas

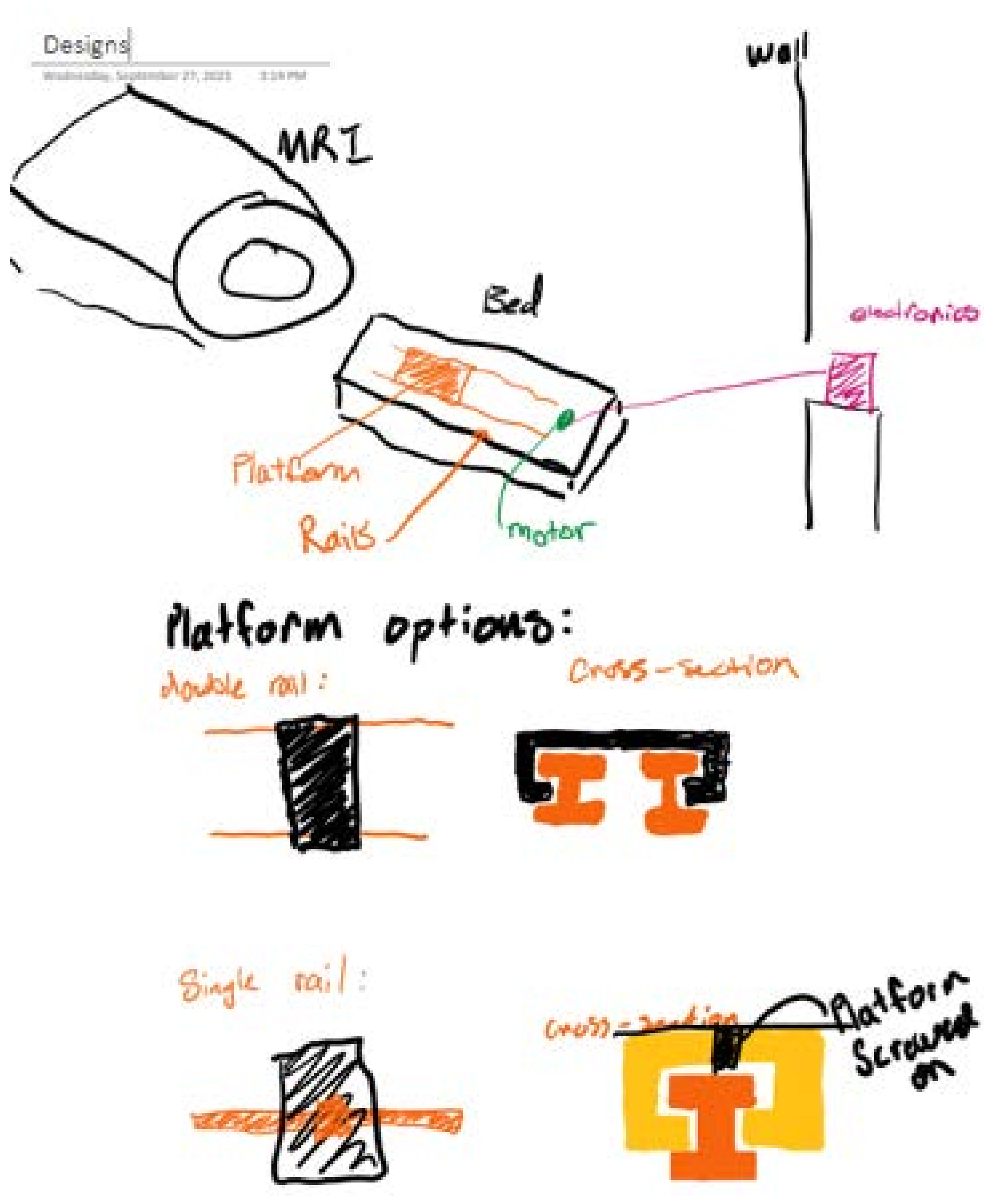
Date: 10/11

Content by: Kendra

Present: Kendra

Goals: To document the design idea I came up with and shared with the group

Content:



Conclusions/action items:

I drew two designs to situate the platform to the bed. One being a single rail design and the other being a double rial design. The single rial would be easier to manufacture and replicate however the double rail would provide more stability.

2023/10/25 - Mbed learning

Kendra Besser - Dec 13, 2023, 1:43 PM CST

Title: mbed learning

Date: 10/25

Content by: Kendra

Present: Kendra

Goals: To document helpful learning guides to code in mbed

Content:

What is mbed:

- codes ARM microcontrollers
- 32 bit
- we are using FR01RE (www.st.com/stm32nucleo)
- codes in C++ (but can convert languages?)
- a development platform and real-time operating system (RTOS) designed for internet-connected devices
- connects to work with Arm Cortex-M based hardware
- can include device security and cloud service intergrations

mbed tutorial: https://www.youtube.com/watch?v=BAzKg3vcB88

- for version 2 of mbed (current downoad is 6)
- getting started how to create a new file

https://os.mbed.com/

- mbed home page
- download on computer to use (newest version is 6)
- https://os.mbed.com/platforms/ST-NUCLEO-WB15CC/
    - documentation of white board
- https://os.mbed.com/platforms/MIMXRT1050-EVK/
    - green board documentation
- https://os.mbed.com/teams/mbed-os-examples/code/mbed-os-example-blinky/
    - start with blinky code to ensure mbed is communication with board
    - run the steps that are laid out in the link

Conclusions/action items:

Mbed is a platform that can be used to communicate with a select number of boards. Mbed has multiple libraries and additions that can be included into the code. The next step is to get the blinky program running then edit the given motor code.

2023/11/16- User Input Research

Kendra Besser - Nov 16, 2023, 7:18 AM CST

Title: User Input Research

Date: 11/16/23

Content by: Kendra

Present: Kendra

Goals: identify different methods to create a user interface for input

Content:

BufferedSerial

- has UART functionality
- define a port to write to
- can also print to a console
- used on MBed
- format: https://os.mbed.com/docs/mbed-os/v6.16/apis/serial-uart-apis.html
- example of user input: https://forums.mbed.com/t/how-to-have-user-input-nucleo-f401re/12080/2

Python RPC

- in python call mbed as a port
- potential call mbed to run and then get pop up windows?
- would need to have mbed and code also downloaded (not as efficient)
- example: https://os.mbed.com/cookbook/Interfacing-with-Python

Arduino

- potential example
- just a code on how to do multiple things at once on Arduino
- pretty sure we would need to write code
- https://forum.arduino.cc/t/receiving-user-input-while-running-stepper-motor/344234

python

- attempting to read code from motor but not very variable (might need this specific motor)
- https://www.pololu.com/docs/0J77/8.8

UART

- stm32 serial communication
- download STM32 app which yu ca upload and run code from there
- select UART function
- open taraterm (pop up window to print output and upload input)
    - can print to terminal
    - a bunch of functions of Hal-uart that can print data
- https://www.youtube.com/watch?v=7kUo-ekxmCA

Conclusions/action items:

Next steps moving forward will be to try the BufferSerial in MBED and UART and if that doesn't work then possibly rewrite code on another program or rewire circuit to include potentiometers.

2023/10/11 - Teamlab Documentation

Kendra Besser - Oct 11, 2023, 3:07 PM CDT

Title: Red and Green Permit Certification

Date: 9/14/2022

Content by: Kendra

Present: Kendra

Goals: Record my certificates in the red and green permit from team lab

Content:

see attachment for certificate

Conclusions/action items:

I have completed the red and green permit training and have received a certificate in each of them. I have the skills and ability to use the equipment in the team lab and makerspace in order to fabricate a prototype for the project.

Kendra Besser - Oct 11, 2023, 3:07 PM CDT

[Download](#)

2022-09-14.png.jpg (20.4 kB)

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

Jamie Flogel - Sep 11, 2023, 10:59 AM CDT

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: