Team 534pc: P.R.D.C.T.

Powder Rheometric Device Characterizing Torque

Angel Alvarado Perez | Robert Copsey | Kc Davis | Noah Owens | Logan Smith

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MERRICK INDUSTRIES, INC.
FAMU-FSU College of Engineering

P.R.D.C.T. TEAM

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PROJECT MENTORS

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MERRICK INDUSTRIES

Merrick is a company based in Lynn Haven, Florida that specializes in premium-quality weighing and feeding systems that handle a variety of dry bulk materials and applications.

Website: https://merrick-inc.com/
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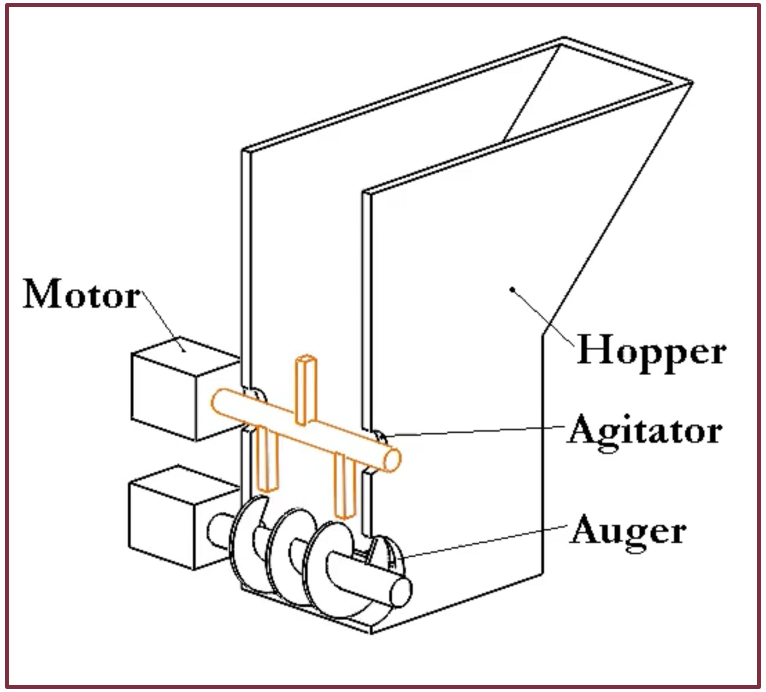
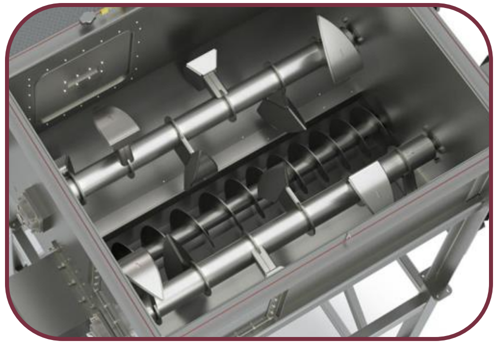
SCREW FEEDERS

Industrial screw feeders regulate the flow of materials into production processes. They consist of four primary components.



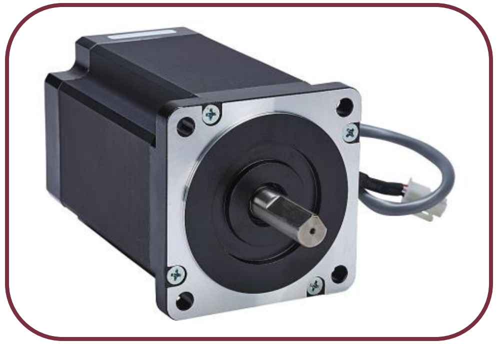
Industrial Screw Feeder Components

Hopper
- Holds material as it awaits feeding



Agitator
- Helps material flow toward auger

Auger
- Feeds material at a controlled rate



Motors
- Drive agitator and auger

PROJECT MOTIVATION

Motor sizing is critical

- Undersized motors results in a defective feeder
- Oversized motors result in unnecessary cost and component damage

Motor sizing is primarily determined by the required torque and speed needed to handle the load

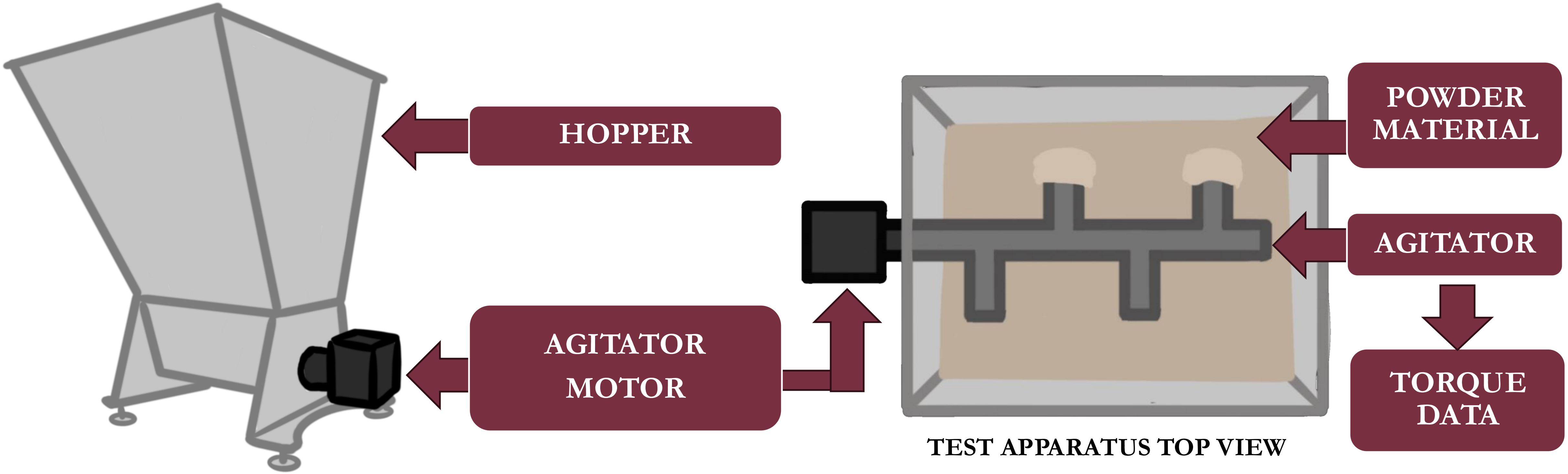
- Material amount, material properties, and agitator geometry directly affect this torque.

Currently, the relationship between the feeder material, agitator geometry and required torque is not well understood.

- Many companies in the feeding industry select motors based on experience.

PROJECT SCOPE

The goal of this project is to design and build a TEST APPARATUS that allows the collection of data regarding the agitation torque for various powdered materials and agitator geometries to then create an empirical model to anticipate motor sizing



TEST APPARATUS TOP VIEW

CUSTOMER NEEDS

Customer Statement	Interpreted Need
"It (motor selection) is currently based on experience. It is challenging to estimate the motor size without having issues."	The device provides quantitative, reliable, and repeatable results.
"The scale (of the device) must be big enough to be meaningful and small enough for easy fabrication"	The device produces measurable and representative data, but still small enough to remain practical and cost-effective to build and handle (i.e., benchtop).
"The device must capture torque data quickly enough to reflect real variations and provide reliable results."	The device samples torque data at a sufficient rate to accurately capture variations to ensure reliable results.
"In order of priority, it (the device) must be useful, manufacturable, safe, and cost-effective"	The device prioritizes outputting usable data and ease of operation.

DESIGN GOALS

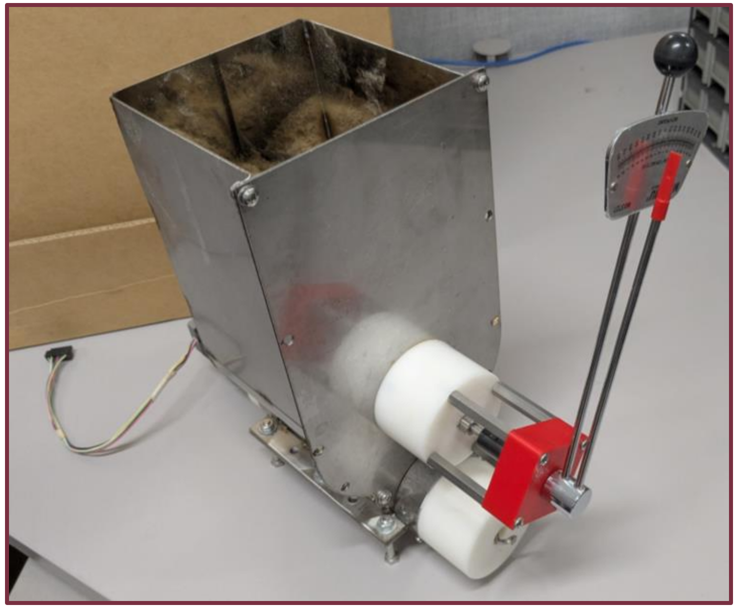
- Geometrically similar to an Industrial Feeder
- Modular Design with Simple Fabrication
- Handle a variety of Powder Material
- Interchangeable Agitator
- Robust Build
- Operate at Industrial Agitation Speeds
- Precisely Control Agitation Speeds
- Capable of Torque and Time Data Acquisition

WORK SCHEDULE

1/19/2026 - 2/16/2026	
Test Apparatus Conceptual Design.	
2/17/2026 - 3/16/2026	
Prototype 1 Build.	
3/17/2026 - 4/13/2026	
Test and Refine	Collect Data
4/14/2026 - 4/17/2026	
Initial Design Review	
4/18/2026 - 4/27/2026	
Collect Data	Prototype 1 Review
4/28/2026 -6/08/2026	
Prototype 2 Design	Prototype 2 Build
6/09/2026 - 07/20/2026	
Collect Data	Mathematical Model
7/21/2026 - 7/28/2026	
Final Design Review	

FINDING MAXIMUM TORQUE

Experimental Procedure:



Experimental Feeder

An analog torque wrench was fixed onto a modified feeder that had a socket attached to the agitator in place of the motor.

Torque readings were observed as the agitator was spun by the operator manually applying force to the torque wrench when the hopper was loaded with "powder" materials (sawdust, sand).

Analog Torque Wrench

FINDING MAXIMUM TORQUE

Experimental Results:

	Sawdust	Sand
Starting Torque	25 in-lb	35 in-lb
Running Torque	15 in-lb	20 in-lb

Calculating the maximum torque, with a design factor of 1.4*

$$T_{max} = T_{allowable} * n_d = (35 \text{ in} - \text{lb})(1.4) = 49 \text{ in} - \text{lb}$$

*Design factor agreed upon collaboratively with MERRICK INDUSTRIES, INC.

DESIGN CONSIDERATIONS

Sample Rate

Data collection should be fast enough to discern important trends, but within the limits of commercial scales as specified with our customer

Operating Speed

Motor rotation should be able to attain speeds equal to that of industrial feeders as specified with our customer

Component Size

Designed parts must fit within the 3D print bed for efficient use of time and cost as well as printed in one piece for enhanced part strength and reduce the need of fasteners

Bambu X1C 3D Printer

MERRICK INDUSTRIES, INC.

FAMU-FSU
College of Engineering

METRICS

Metric	Value	Justification
Withstand Maximum Torque	50 in-lbs	Torque Experiment
Minimum Sampling Rate	10 Samples/Second (SPS)	Customer Standard
Maximum Operating Speed	100 rpm	Customer Standard
Maximum Fabrication Size	10" x 10" x 10"	Available Resource

FUNCTIONS

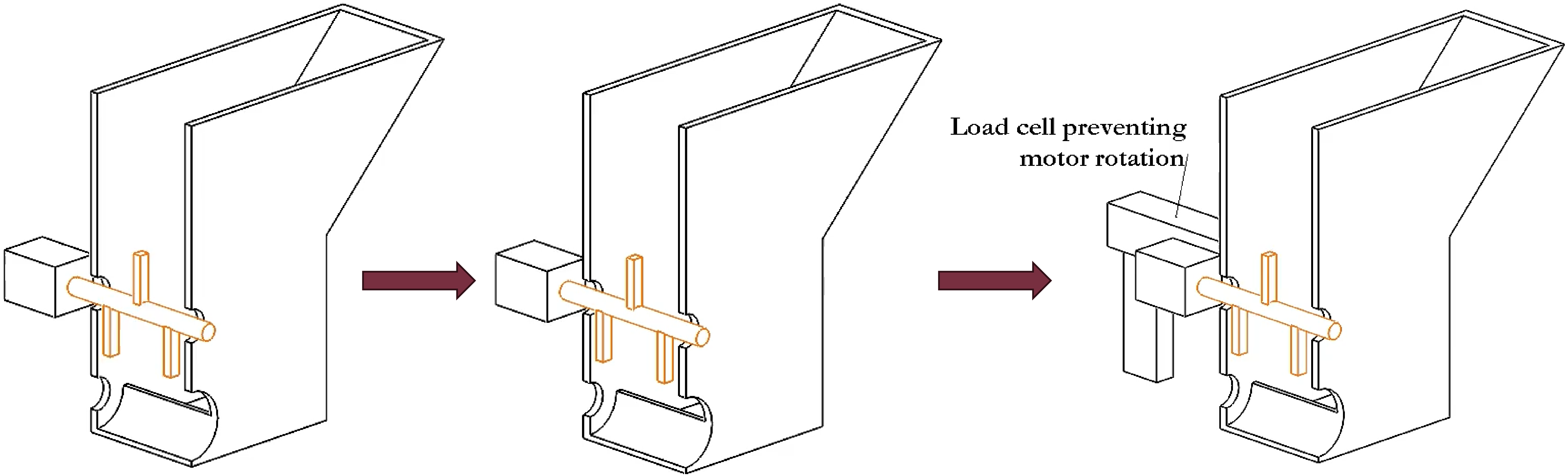
Material Agitation

- Material Enclosure
- Torque Application
- Motor Control
- Safety Control

Data Collection

- Sampling Rate
- Digital Conversion
- Signal Conditioning
- Data Logging
- Calibration

MEASURING REACTION FORCES



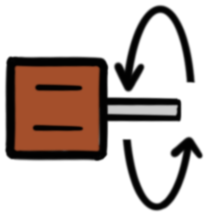
MORPHOLOGICAL CHART

Enclosure Material	Motor Support System	Force Measurement	Material Agitation	Data Storage
PLA	Free standing	Beam load cell	Brushed DC motor	SD card
ABS	Overhang support	Button load cell	Brushless DC motor	USB to PC
PETG	Load cell support	Column load cell	Stepper motor	Bluetooth to PC
	Front plate support			

CONCEPT #1

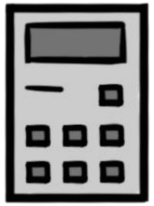
ABS enclosure, front plate supported motor

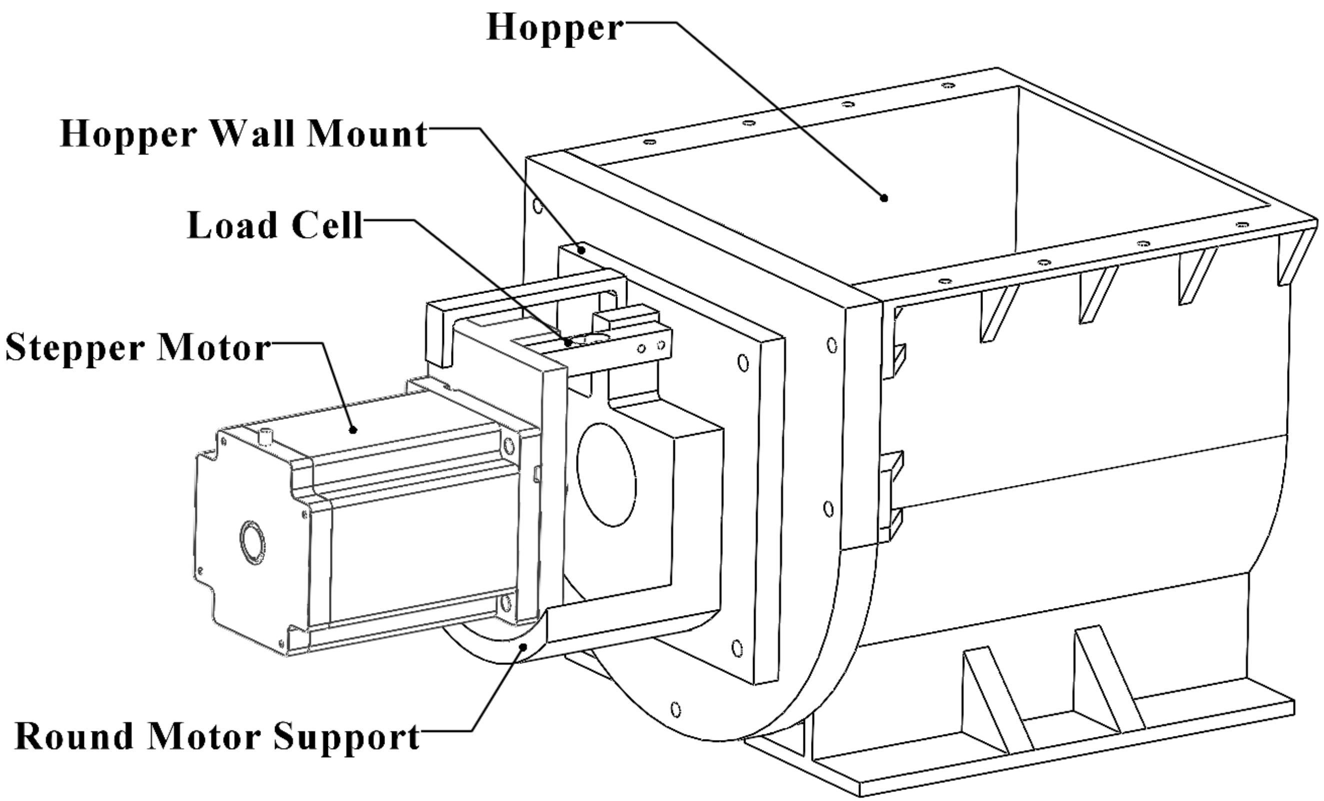
Stepper motor



Arm applies force to beam load cell

SD card with CSV files





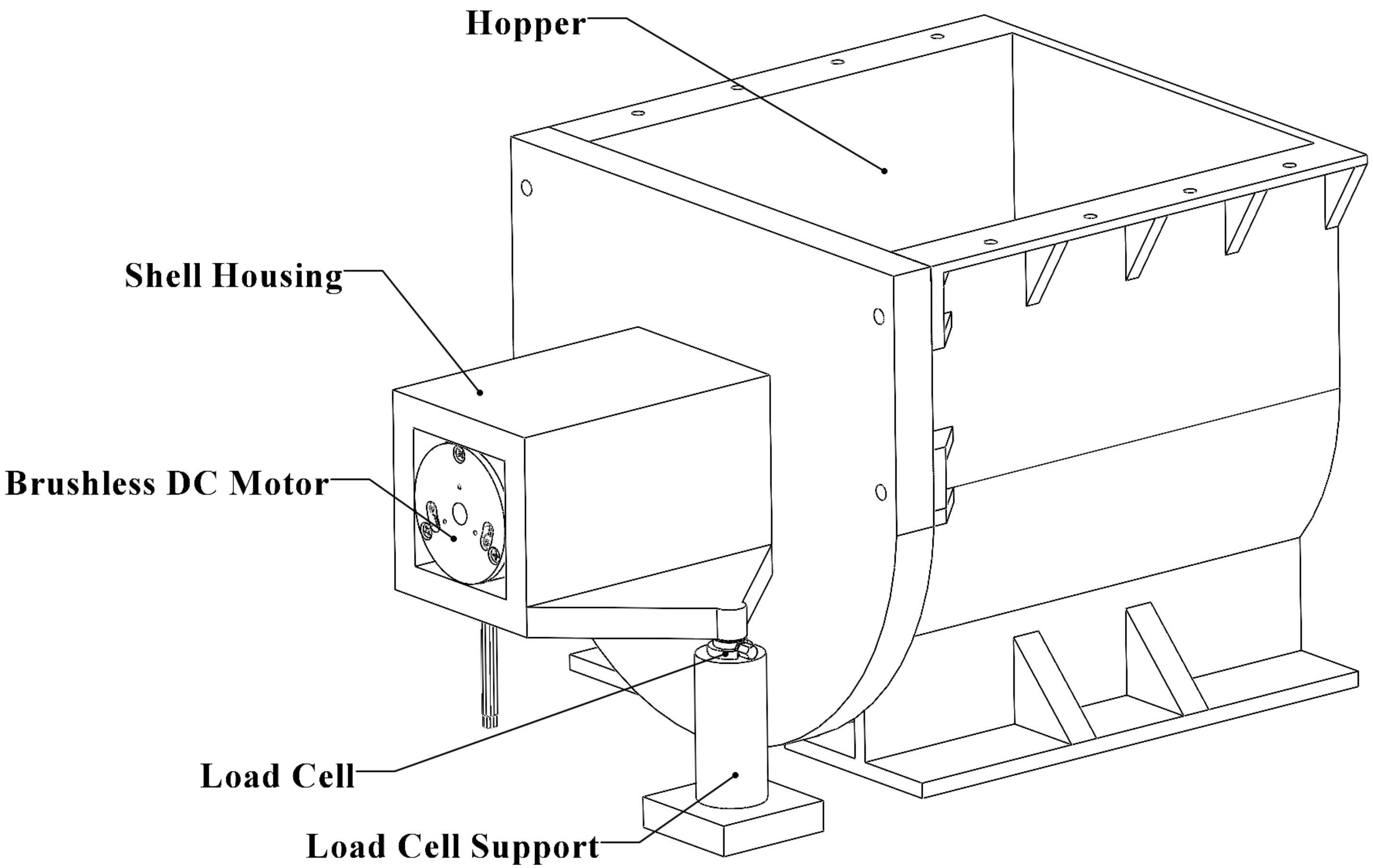
CONCEPT #2

PLA enclosure, free standing motor structure

Brushless DC Motor

Arm applies force to button load cell

Data written directly to PC via USB port



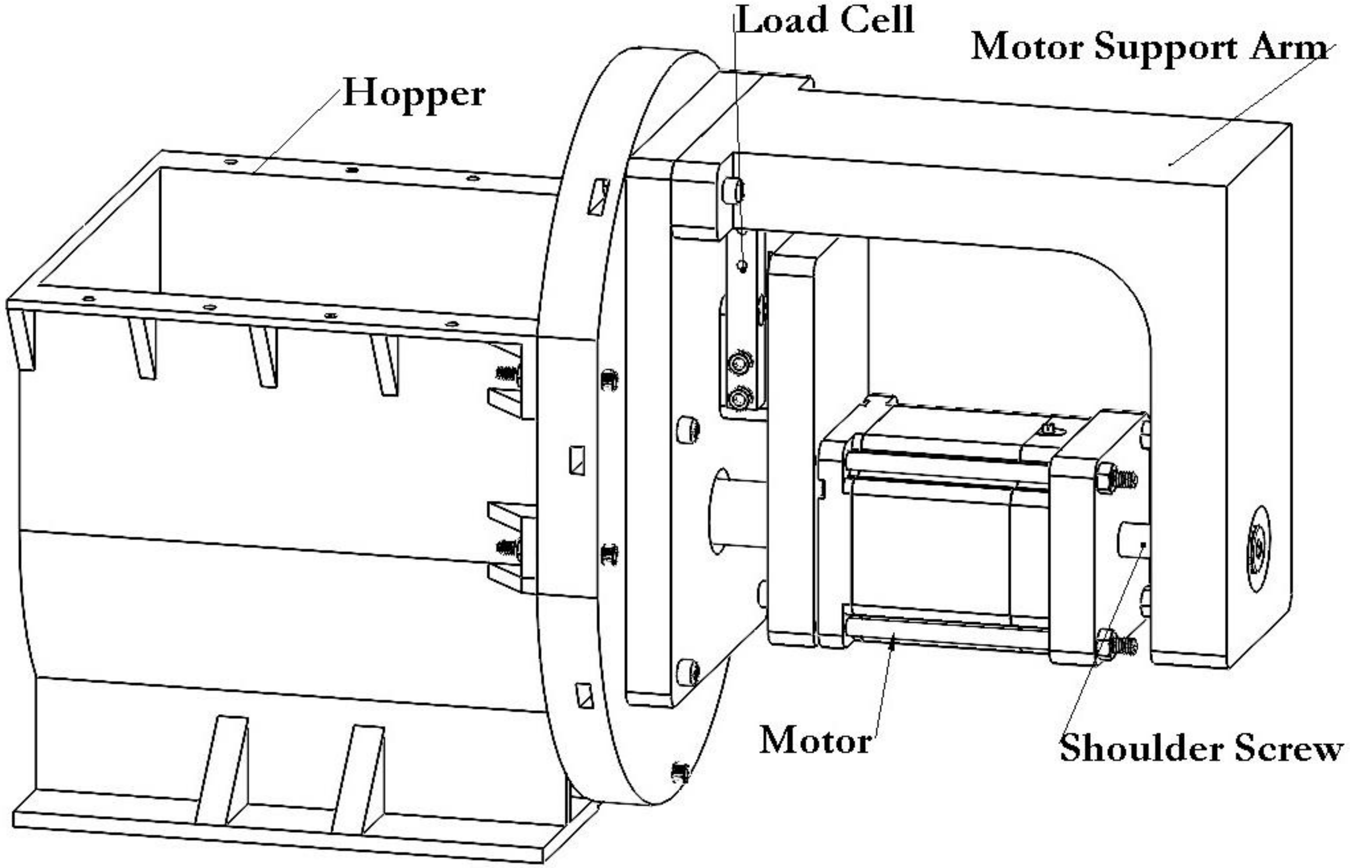
CONCEPT #3

PLA enclosure, plate overhang mounted load cell

Stepper motor

Arm applies force to beam load cell

Data written directly to PC via USB port



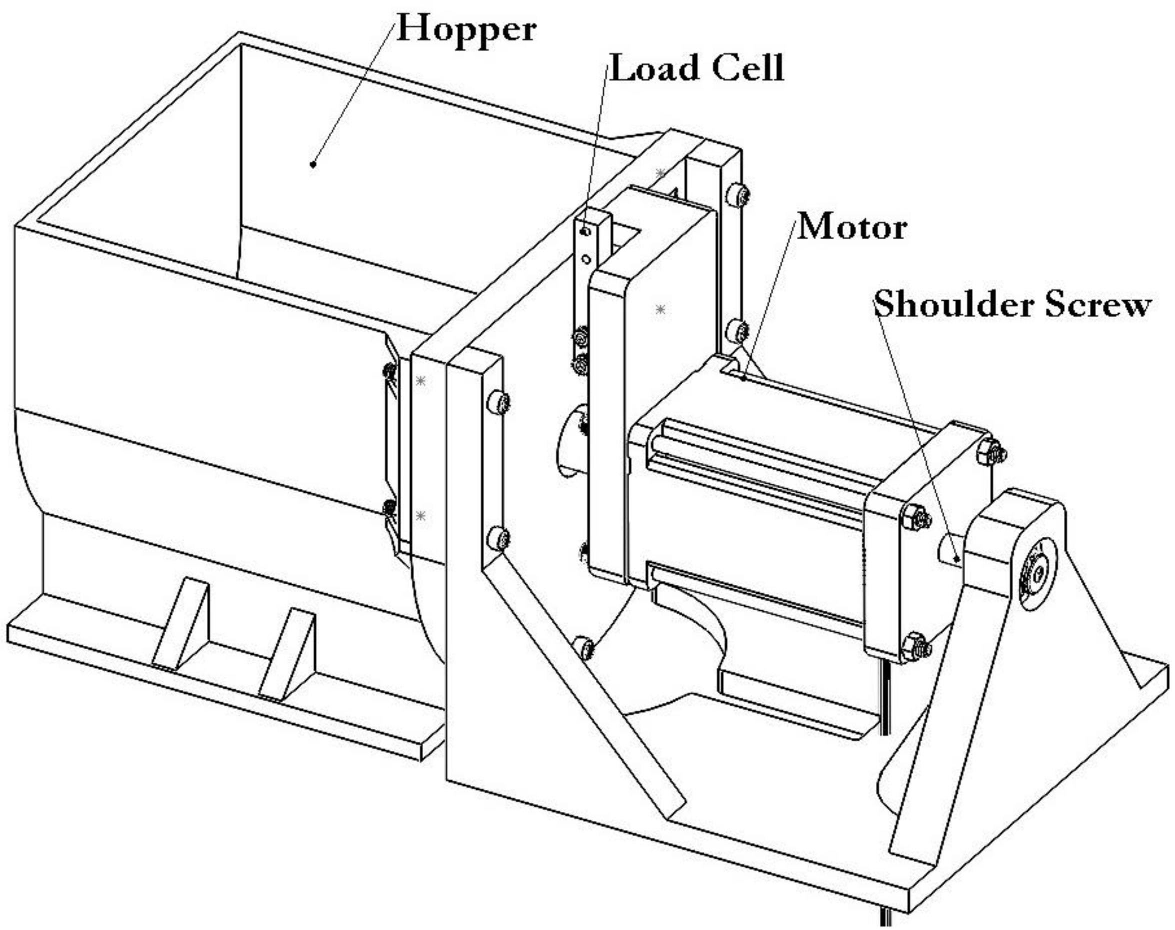
CONCEPT #4

PETG enclosure, free standing structure

Stepper motor

Arm applies force to beam load cell

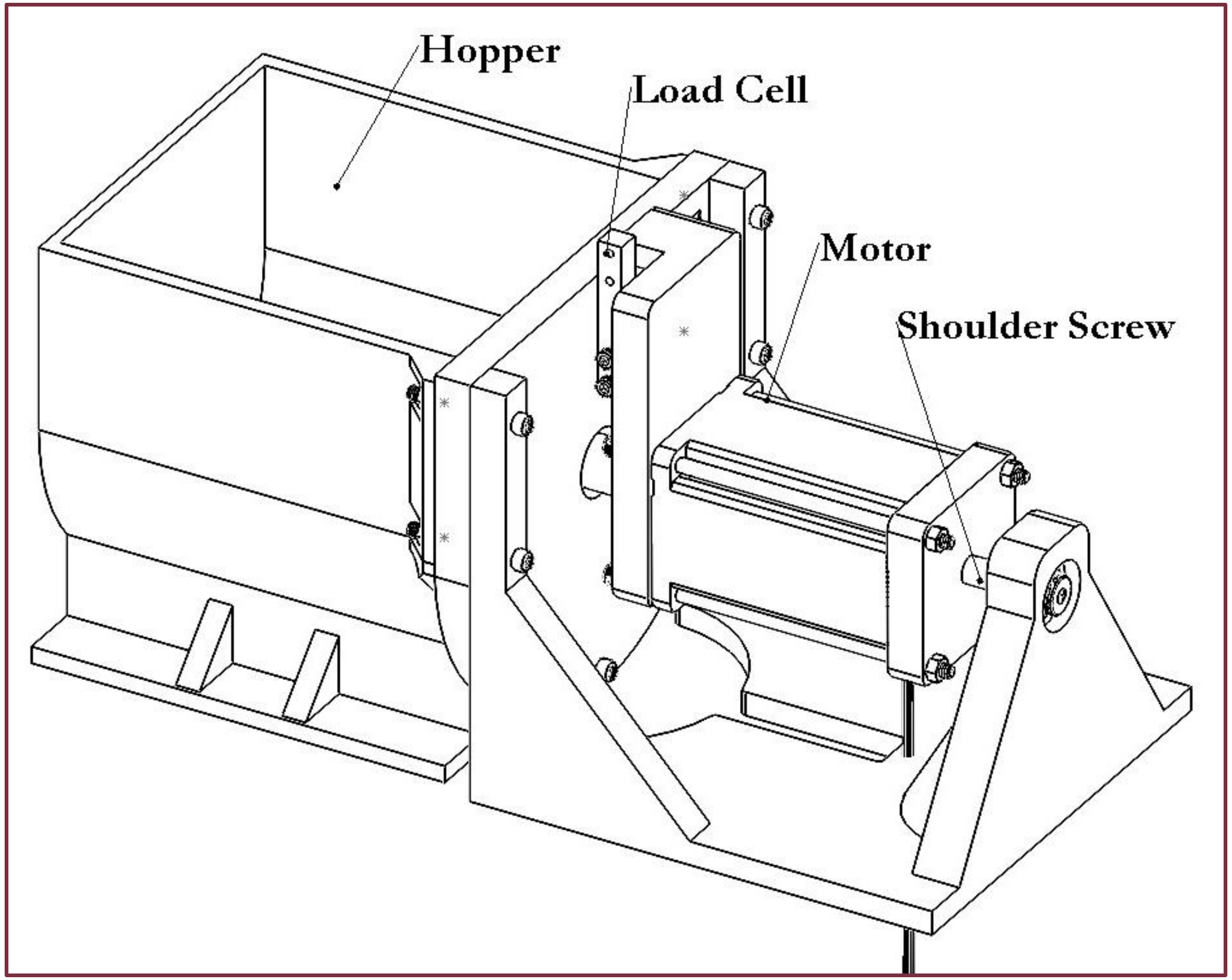
Data written directly to PC via USB port

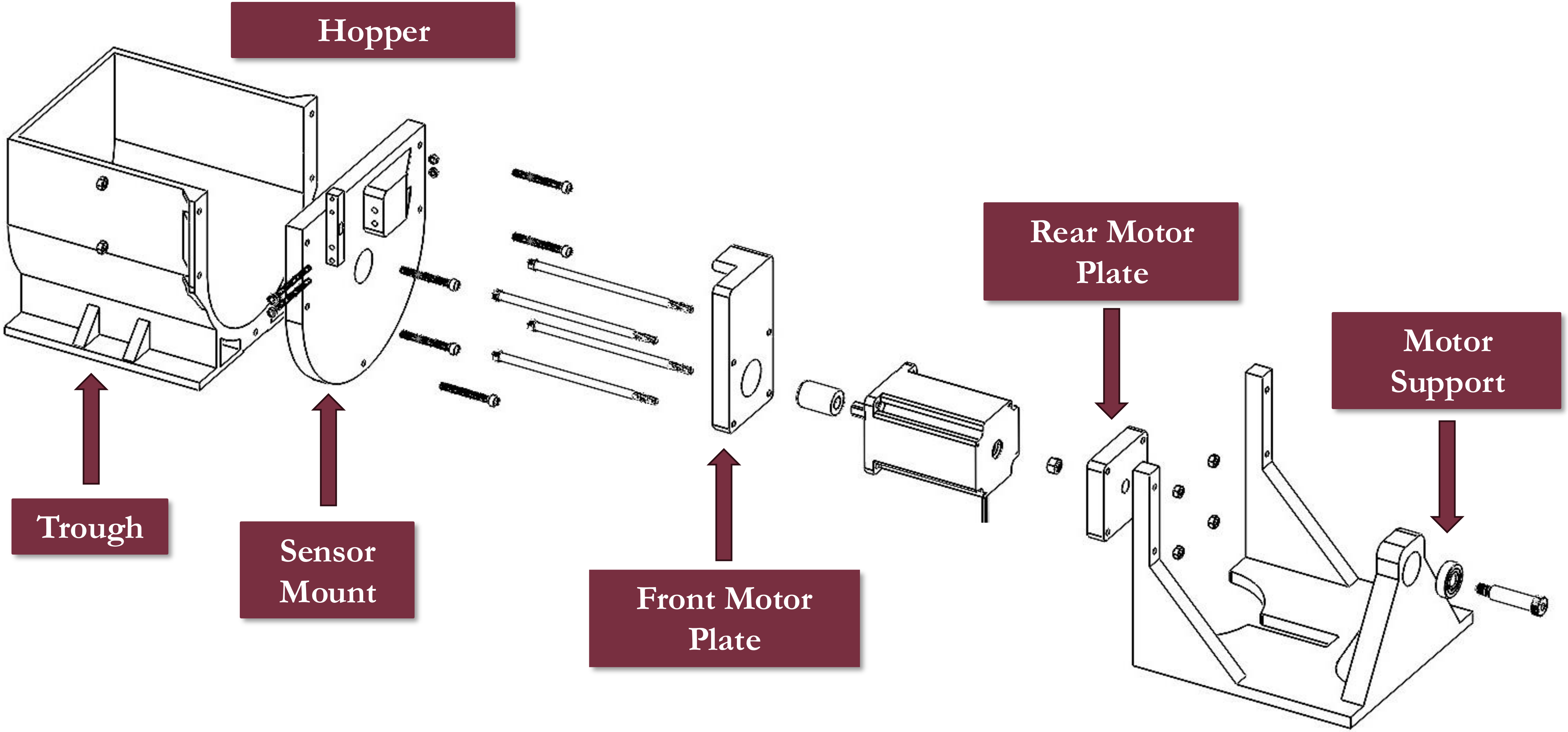


DECISION MATRIX

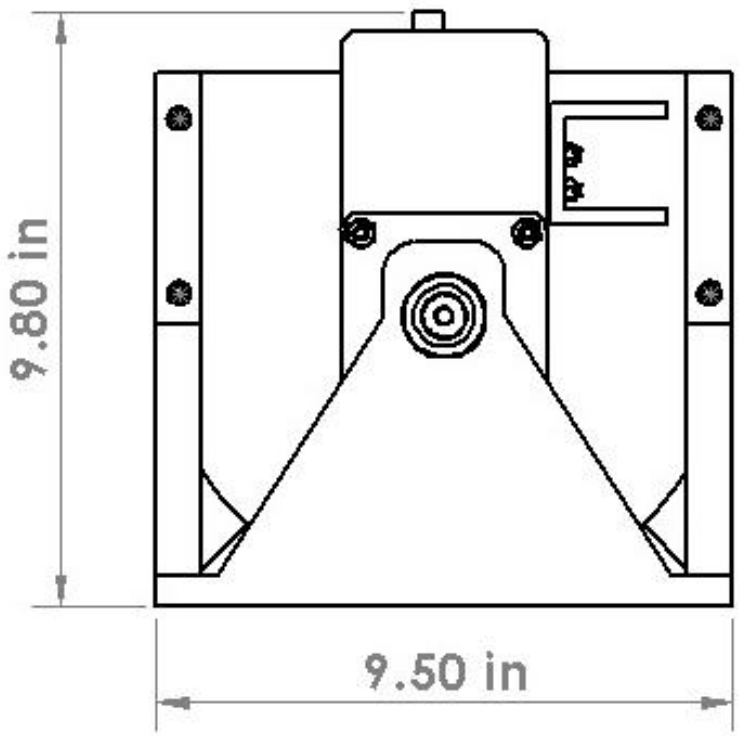
Category	Weight	Concept #1		Concept #2		Concept #3		Concept #4	
	(1-100)	Rating (0-5)	Score	Rating (0-5)	Score	Rating (0-5)	Score	Rating (0-5)	Score
Relatability	25	5	125	2	50	5	125	5	125
Modularity	20	4	80	4	80	3	60	3	60
Ease of Use	15	2	30	5	75	5	75	5	75
Manufacturability	15	3	45	5	75	3	45	5	75
Safety	15	3	45	4	60	4	60	5	75
Cost	10	4	40	4	40	3	30	3	30
Total Score:			365		380		395		440

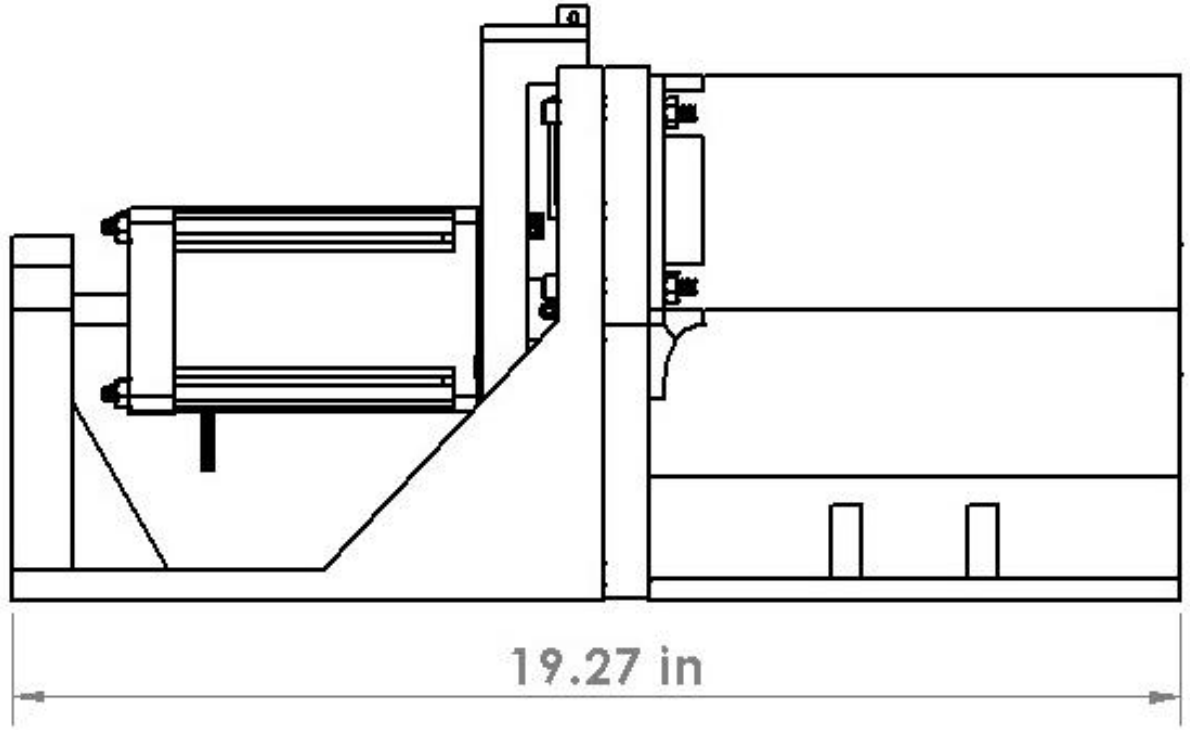
CONCEPT SELECTION – CONCEPT #4




Hopper
Rear Motor Plate
Motor Support
Trough
Sensor Mount
Front Motor Plate

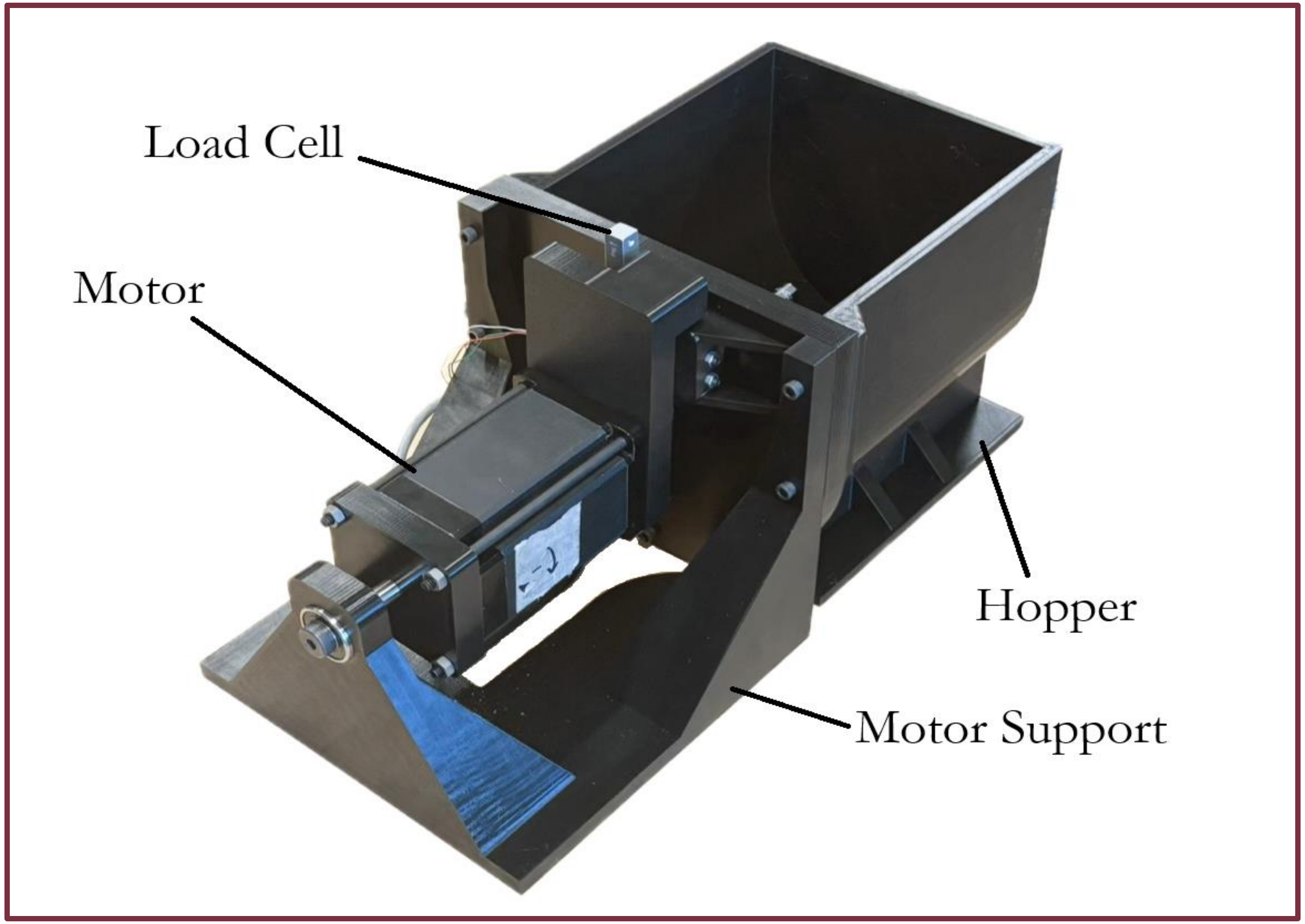
PROTOTYPE 1 DIMENSIONS



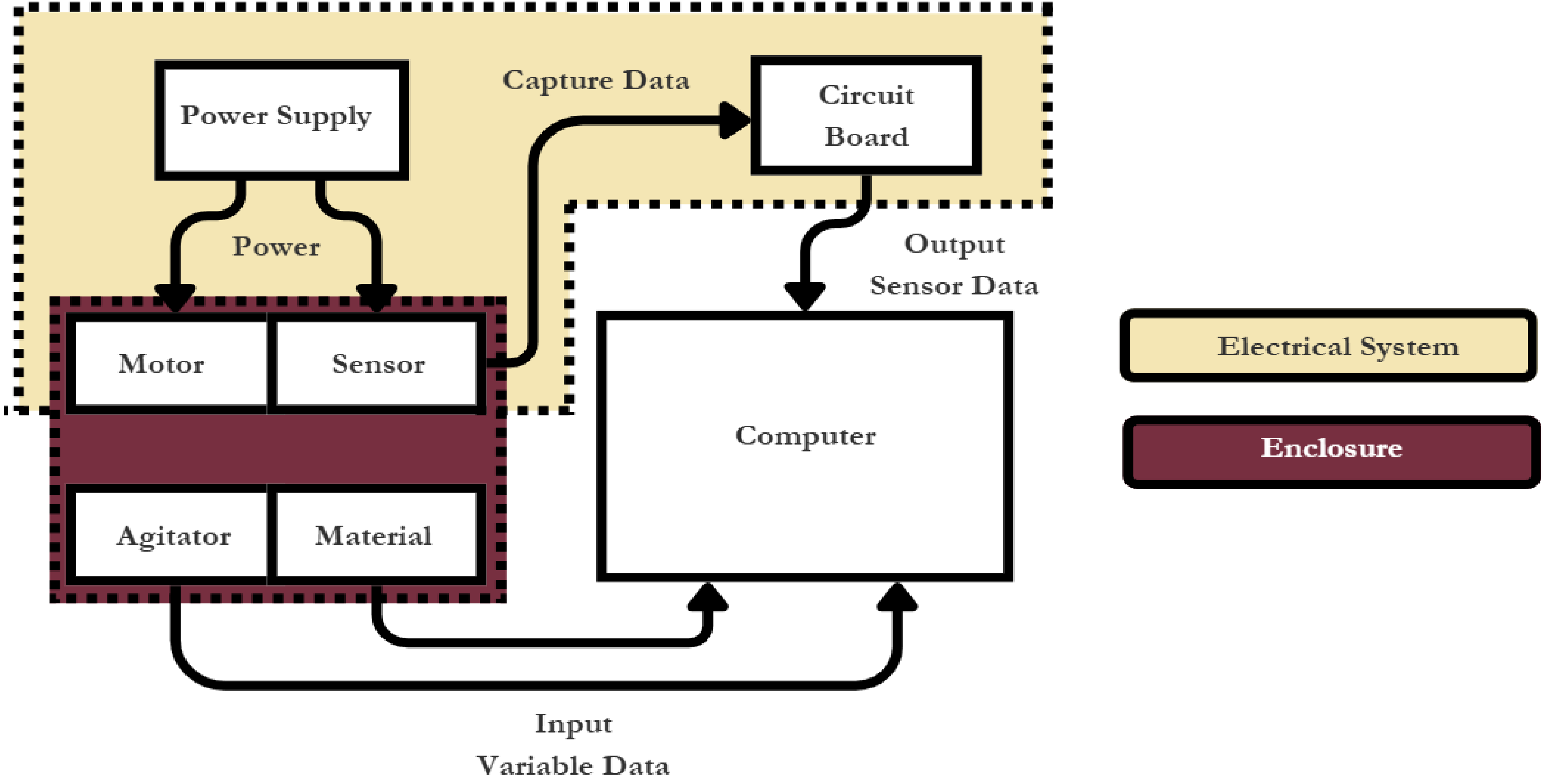


Prototype 1 Hopper Volume: 433 Cubic Inches

PROTOTYPE 1



PROTOTYPE 1 – FUNCTION DIAGRAM



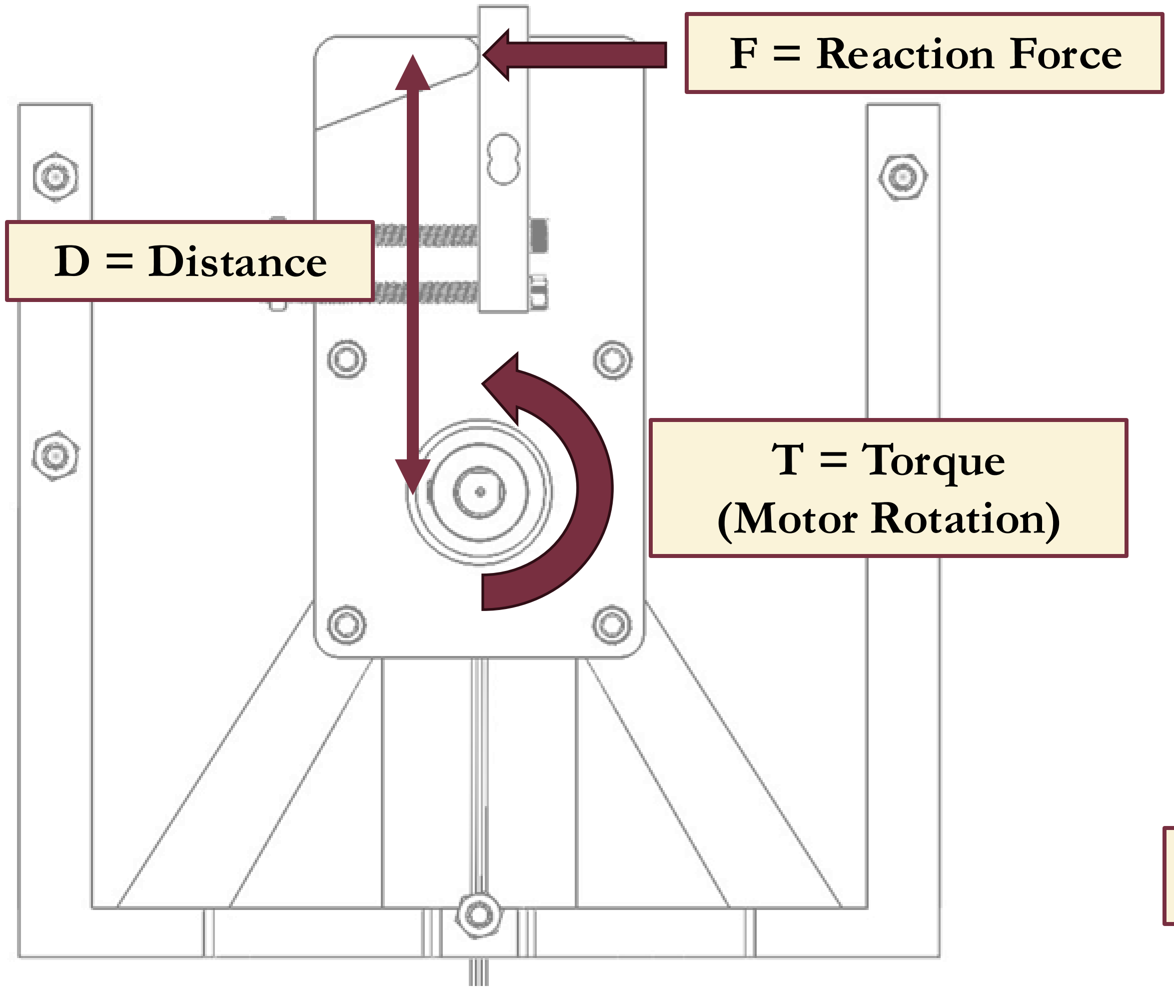
BILL OF MATERIALS

Description	Part Number	Vendor	Quantity	Unit Price ($)	Total Price ($)
Shaft Coupler (0.5” to 0.5”)	6412K14	McMaster Carr	1	17.73	17.73
Jumper Wires (20)	PRT-12795	Mouser Electronics	1	2.95	2.95
1/4”-20 x 7” SHS	91251A908	McMaster Carr	4	5.17	20.68
1/4”-20 Hex Nut	95505A601	McMaster Carr	9	0.57	5.13
M5 x 0.5 x 70mm SHCS	91290A201	McMaster Carr	2	1.25	2.50
M5 x 0.8 Hex Nut	90591A260	McMaster Carr	2	1.94	3.88
1/4”-20 x 2.25” SHS	90044A126	McMaster Carr	5	0.68	3.40
3/8”-16 bolt, 1/2” x 2” shoulder	94383A490	McMaster Carr	1	7.14	7.14
3/8”-16 Hex Nut	98797A031	McMaster Carr	1	5.70	5.70
Sealed Bearing	6384K74	McMaster Carr	2	19.80	39.60
Breadboard	BB-32621	Mouser Electronics	1	4.93	4.93

BILL OF MATERIALS

Description	Part Number	Vendor	Quantity	Unit Price ($)	Total Price ($)
Microcontroller	Uno R3	Arduino	1	27.60	27.60
NEMA 34 Stepper Motor	STP-MTRH-34127	Automation Direct	1	201.00	201.00
Stepper Motor Driver	STP-DRV-6575	Automation Direct	1	112.00	112.00
Stepper Motor PSU	PSB48-480s	Automation Direct	1	120.00	120.00
Agitator	-	-	1		
Adafruit 5kg Load Cell	4541	Adafruit Industries	1	3.95	3.95
Load Cell Amplifier	HX711	SparkFun	1	4.95	4.95
USB to Arduino Cable	3021007-06	Mouser Electronics	1	3.20	3.20
PETG Filament		Sunlu	10	11.99	119.90
				Total Cost for Replication:	706.24
		Original Estimate:	$500.00	Current Total Cost:	264.34

PROTOTYPE DISTANCE CALCULATION



$$T = F * D$$

Design Metric

T_{max} = 50 in-lbs

Load Cell Capacity

F_{max} = (5kg) 11 lbs

$$D_{max} = T_{max} / F_{max}$$

D_{max} = 50 in-lbs / 11 lbs = 4.5 in

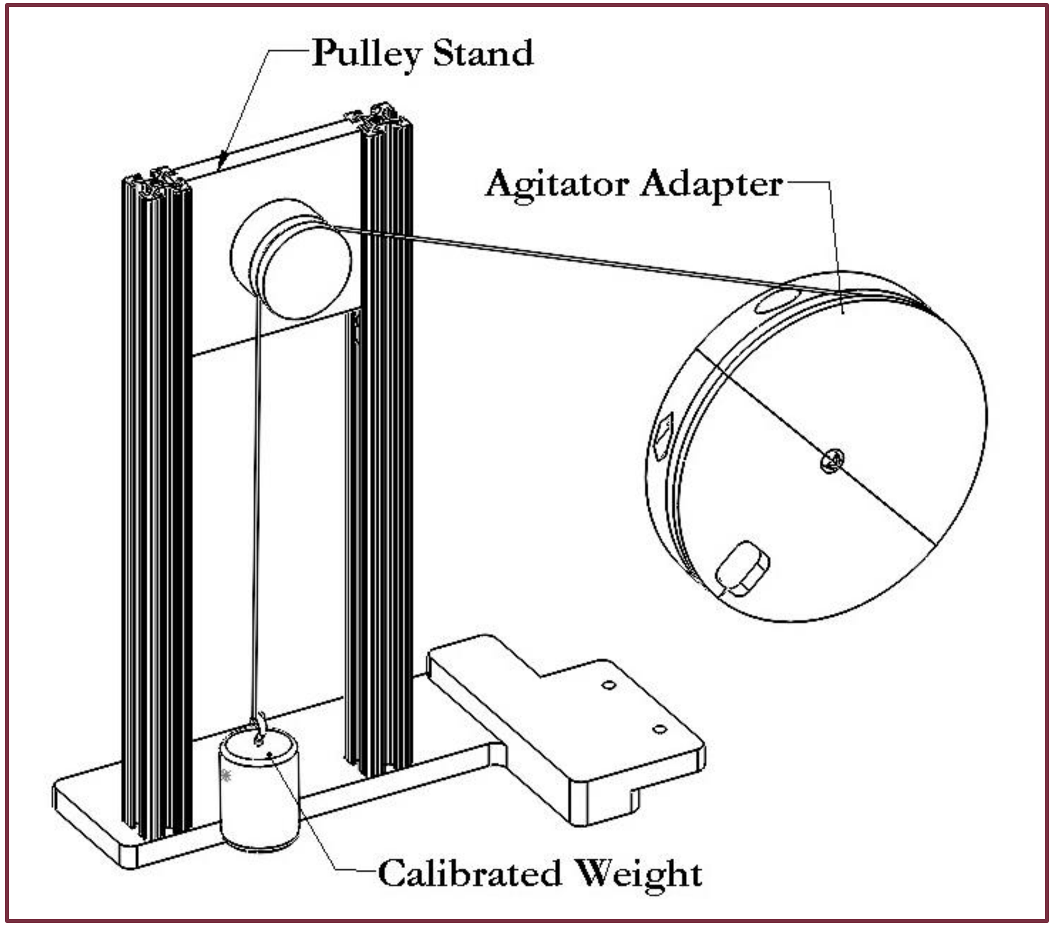
CALIBRATION

Procedure

Apply known weight to test apparatus

Compare sensor output to expected value

Implement a calibration factor to match experimental to expected values



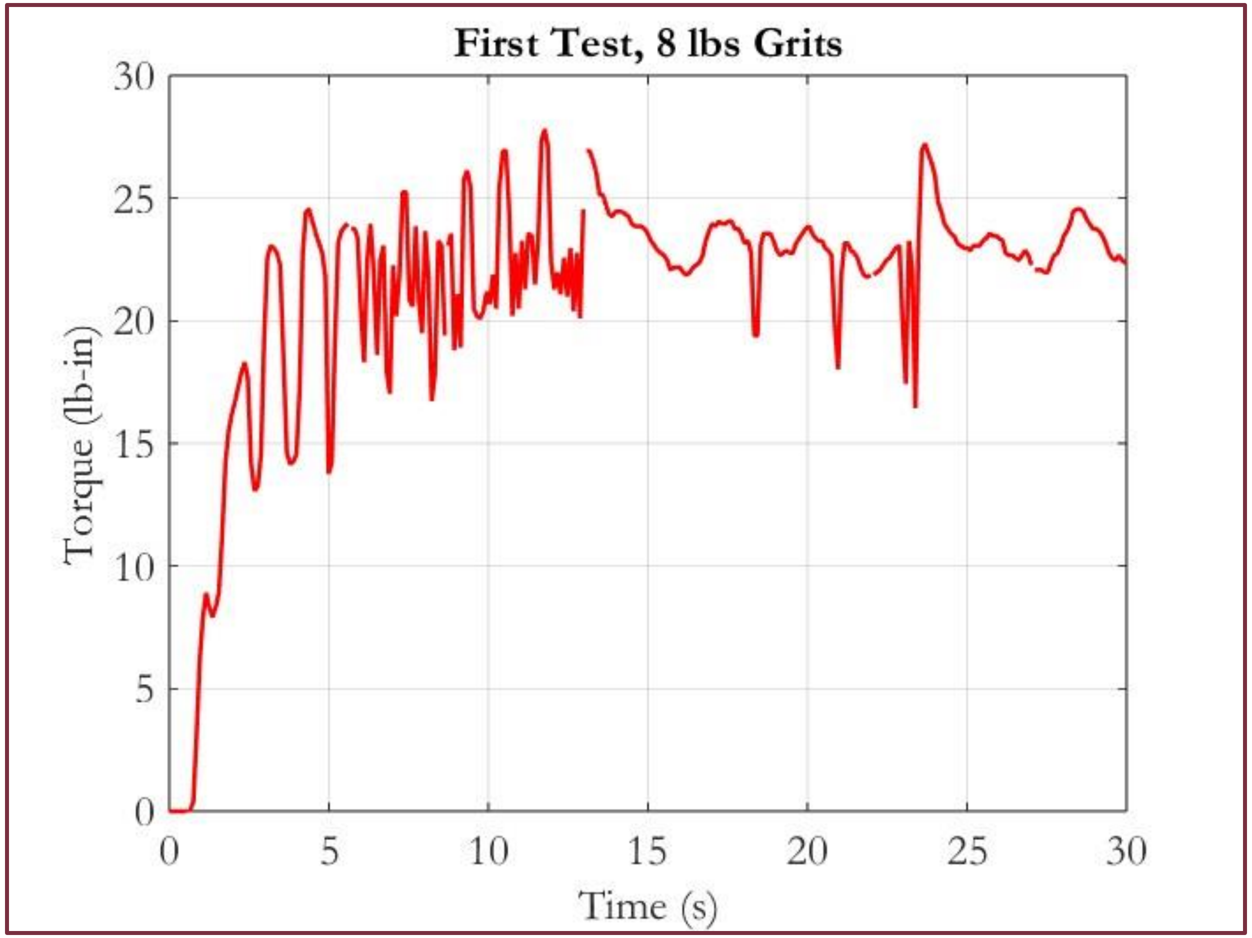
Torque Calibration Device

INITIAL TESTING

Our first test consisted of running the prototype with 8 pounds of grits

At this time, motor control was not fully developed.

Load cell readings were interrupting the CPU communication to the Arduino, resulting in inconsistent motor speed.

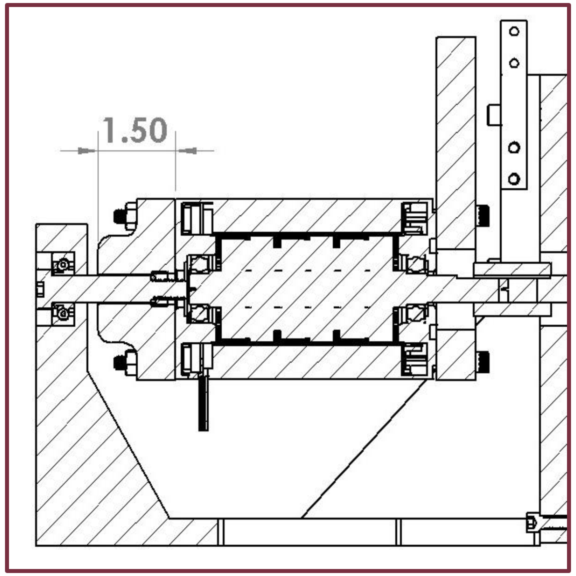


PROTOTYPE 1 REFINEMENTS

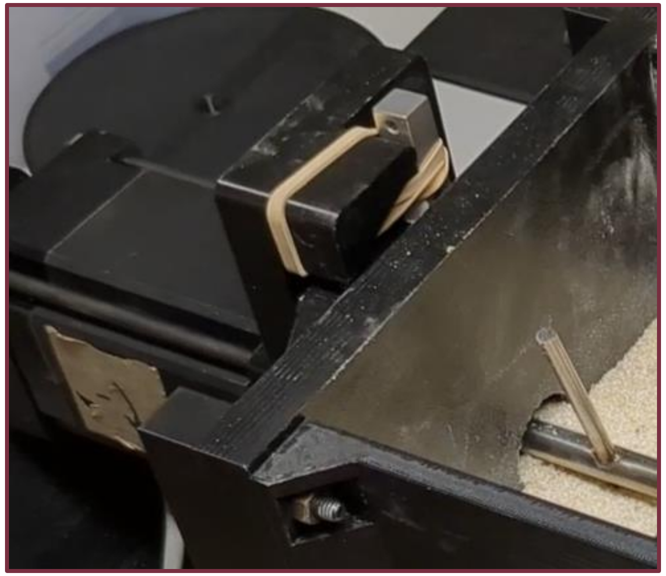
Rear motor plate volume was increased to decrease stress concentration (0.75" to 1.5")

Rubberband added around load cell/motor arm for reliable zero

Improvements were made to the Arduino code for smoother motor operation and data reading.



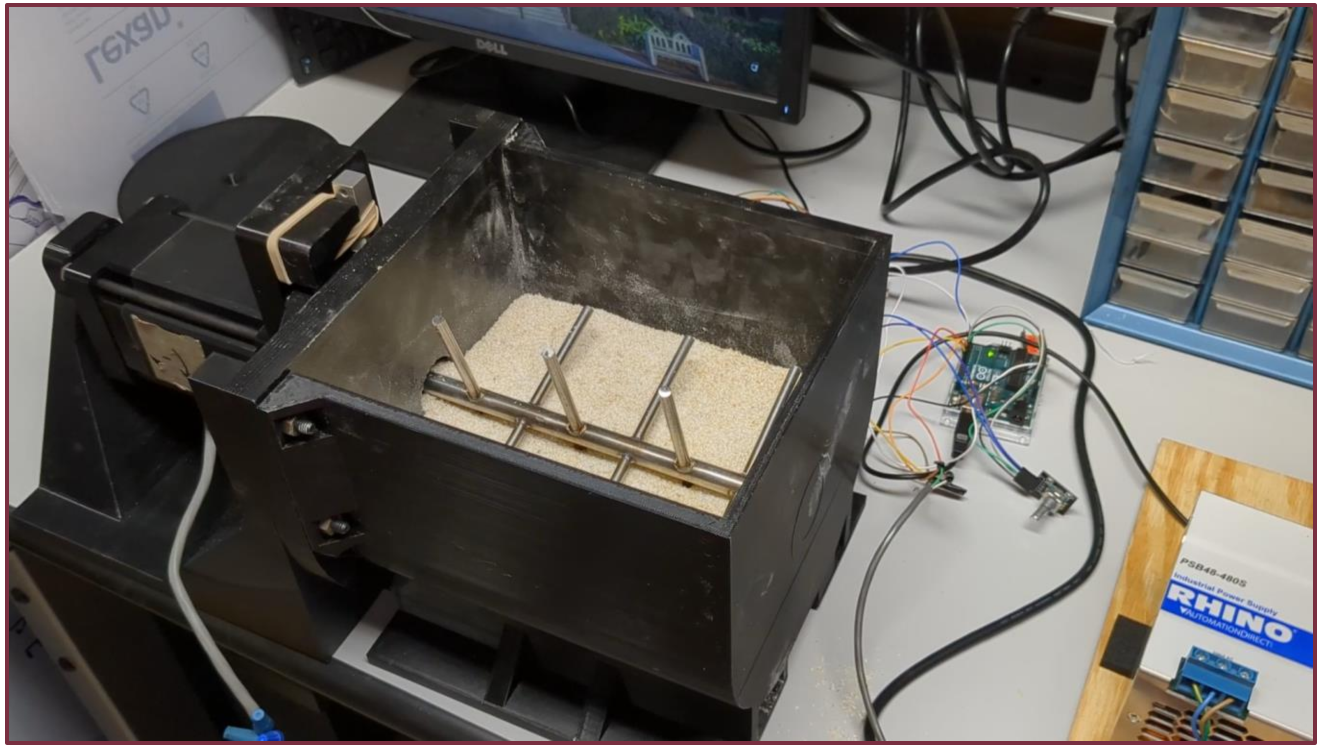
Revised Rear Motor Plate in Device



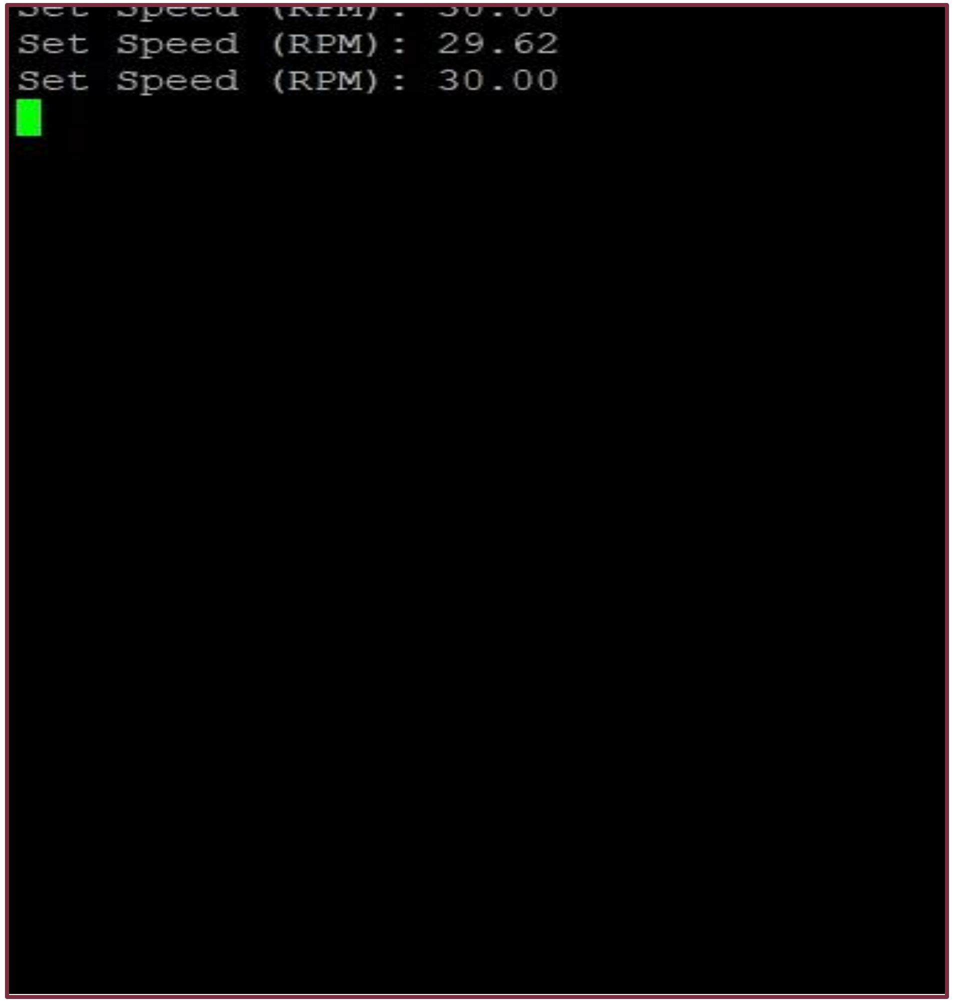
Rubberband around Loadcell and Motor Arm

ADDITIONAL TESTING

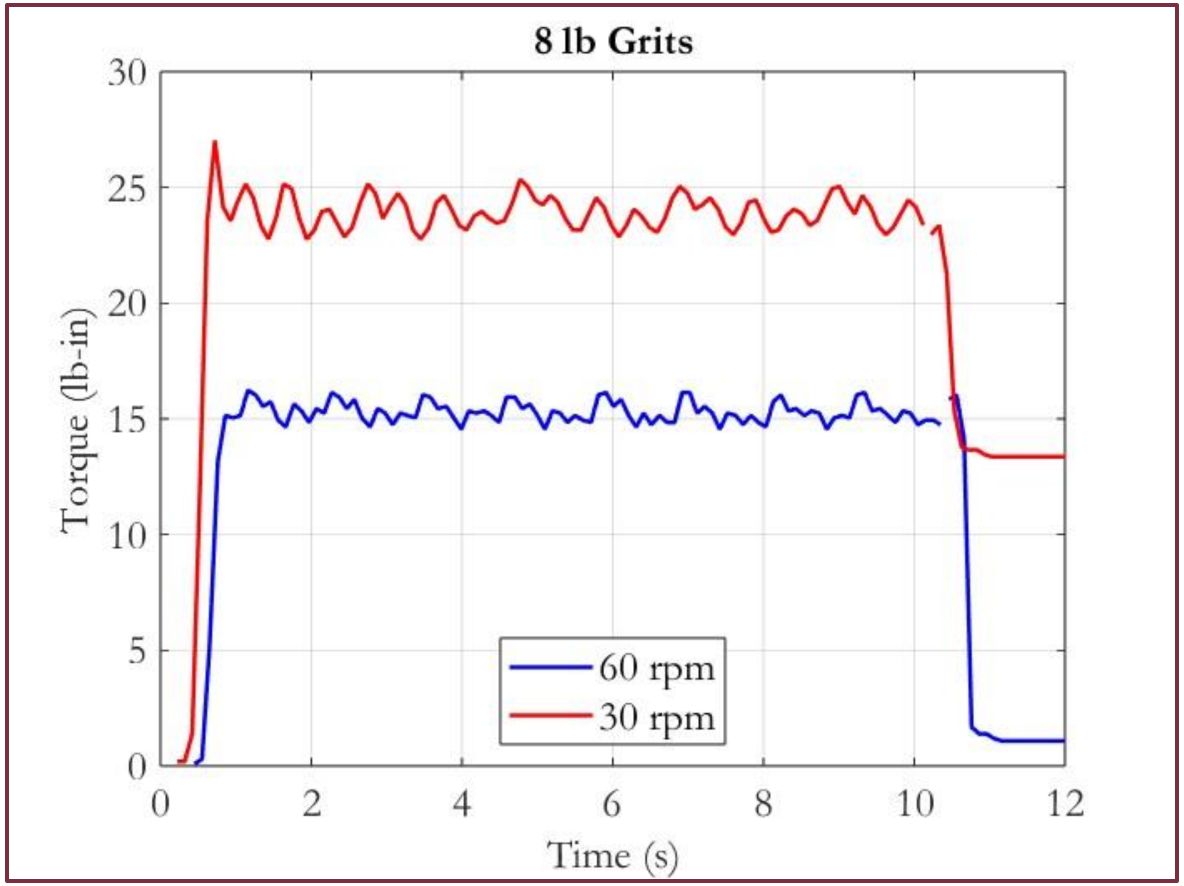
Additional testing consisted of filling the hopper with 5 and 8 pounds of grits while running the agitator at 30 rpm and 60 rpm.

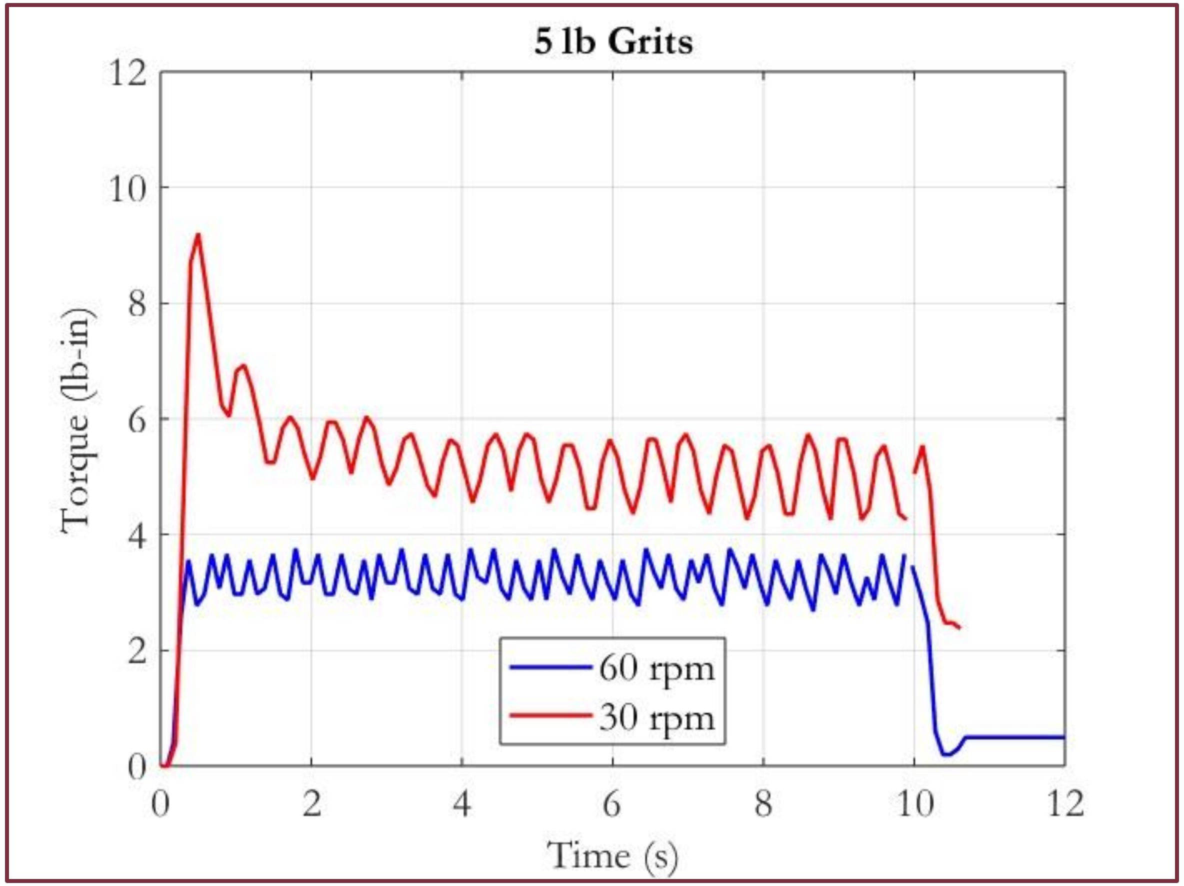


Time | Load | Speed



ADDITIONAL TESTING - CONTINUED





PROJECT TIMELINE

COMPLETED: 2/16/2026	
Test Apparatus Conceptual Design.	

COMPLETED: 3/16/2026	
Prototype 1 Build.	

COMPLETED: 4/13/2026	
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IN PROCESS: 4/17/2026	
Initial Design Review	

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Collect Data	Prototype 1 Review

4/28/2026 -6/08/2026	
Prototype 2 Design	Prototype 2 Build

6/09/2026 - 07/20/2026	
Collect Data	Mathematical Model

7/21/2026 - 7/28/2026	
Final Design Review	

FUTURE BUILD CONSIDERATIONS

- Additional Modularity (Easily interchangeable agitator)
- Larger Hopper Size
- Stainless Steel Hopper
- General Code Improvements
- Integrate a Reliable Zero into Design

THANK YOU!
PROJECT SPONSORS

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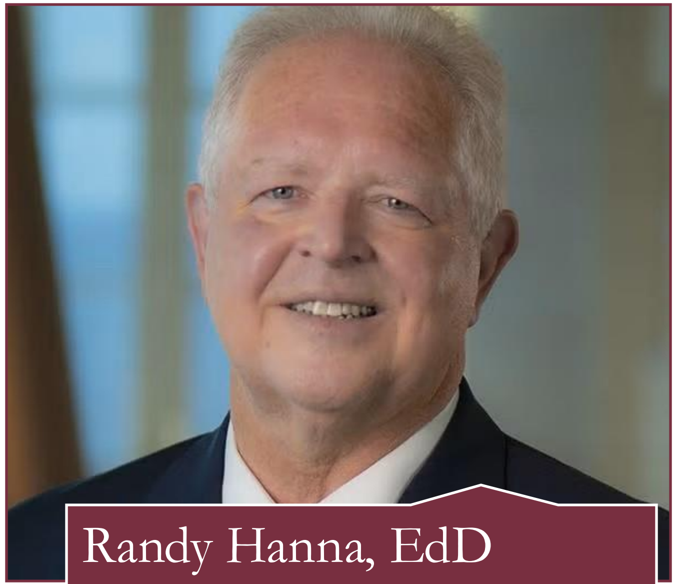
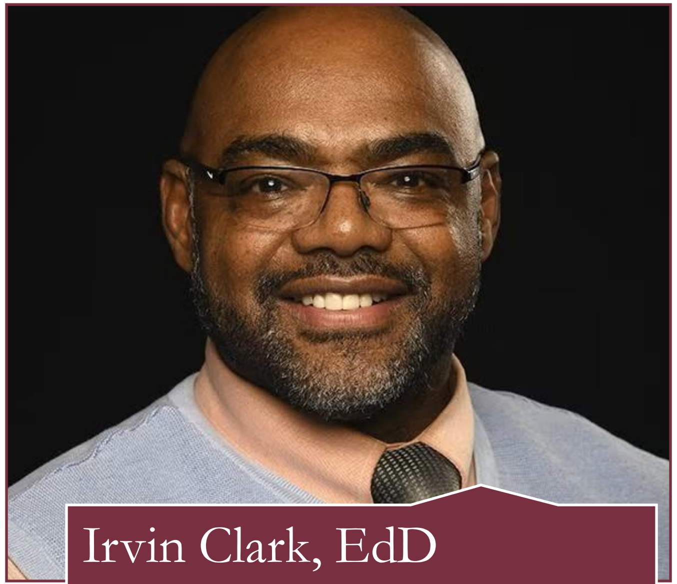
Ed Boardway

Project Mentor, Sponsor



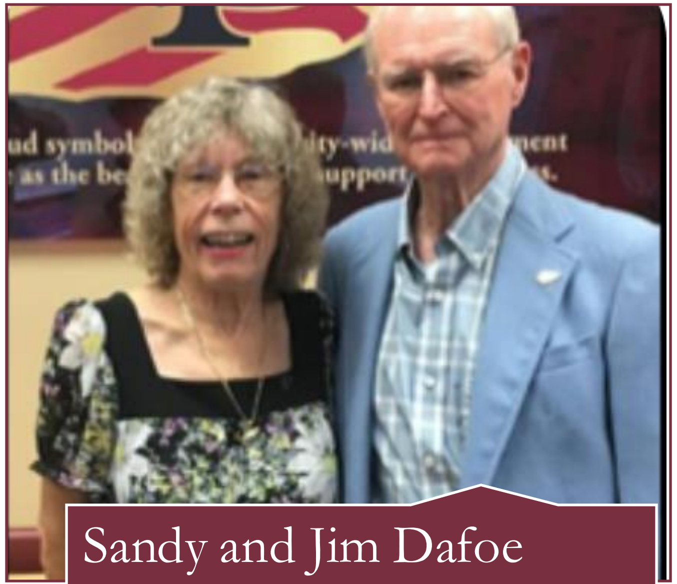
Randy Hanna, EdD

Dean, FSU-PC



Irvin Clark, EdD

Associate Dean, FSU-PC



Sandy and Jim Dafoe

Project Sponsor

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- Image of screw feeder feeding - https://www.trantec.net/screw-feeder/
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- Image of concrete https://jointit.com/blog/what-is-the-difference-between-cement-and-concrete/
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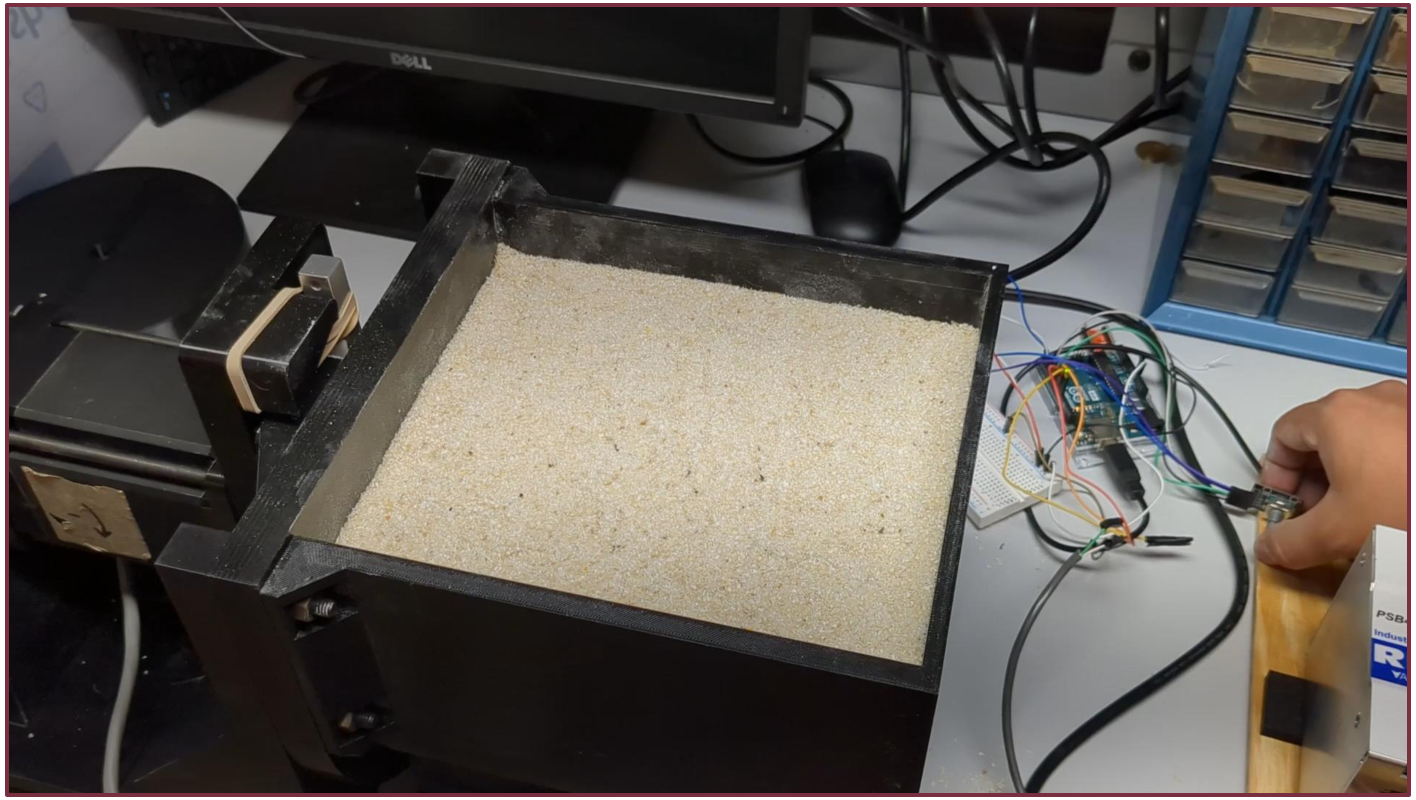
• Types of feeders https://www.kwsmfg.com/engineering-guides/screw-conveyor/types-of-screw-feeders
• Automation Direct - https://www.automationdirect.com/adc/home/home

THANK YOU!
QUESTIONS?

Team Contact | MERRICK Website

https://linktr.ee/PRDCT_FSUPC



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COMPONENTS: TORQUE SENSOR

Pros	Cons
Direct measurement of torque	Expensive
Works in real time (dynamic loads ,turbulence)	Less Versatile
Minimal mechanical assumptions	

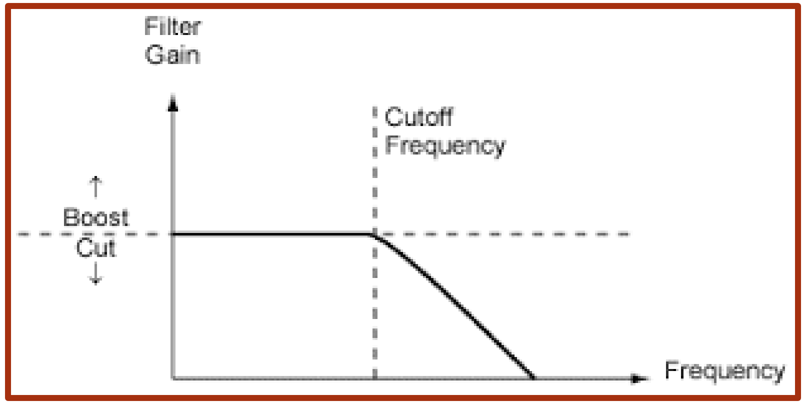
A load cell is preferrable as it will allow for versatility while the design changes and it keeps expenses to a minimum.

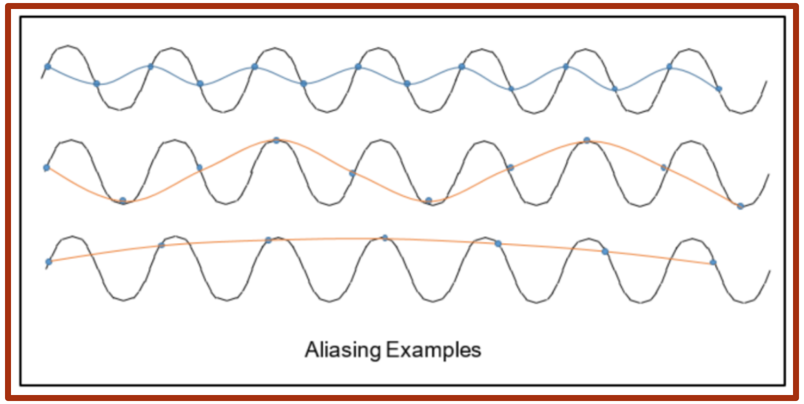
FUTEK Torque Sensor

COMPONENTS: HX711 LOAD CELL AMP

HX711

- 24-ADC
- Amplification (PGA)
- 50/60 Hz Noise Rejection
- Oversampling
- Fixed sample rates : 10 SPS or 80 SPS



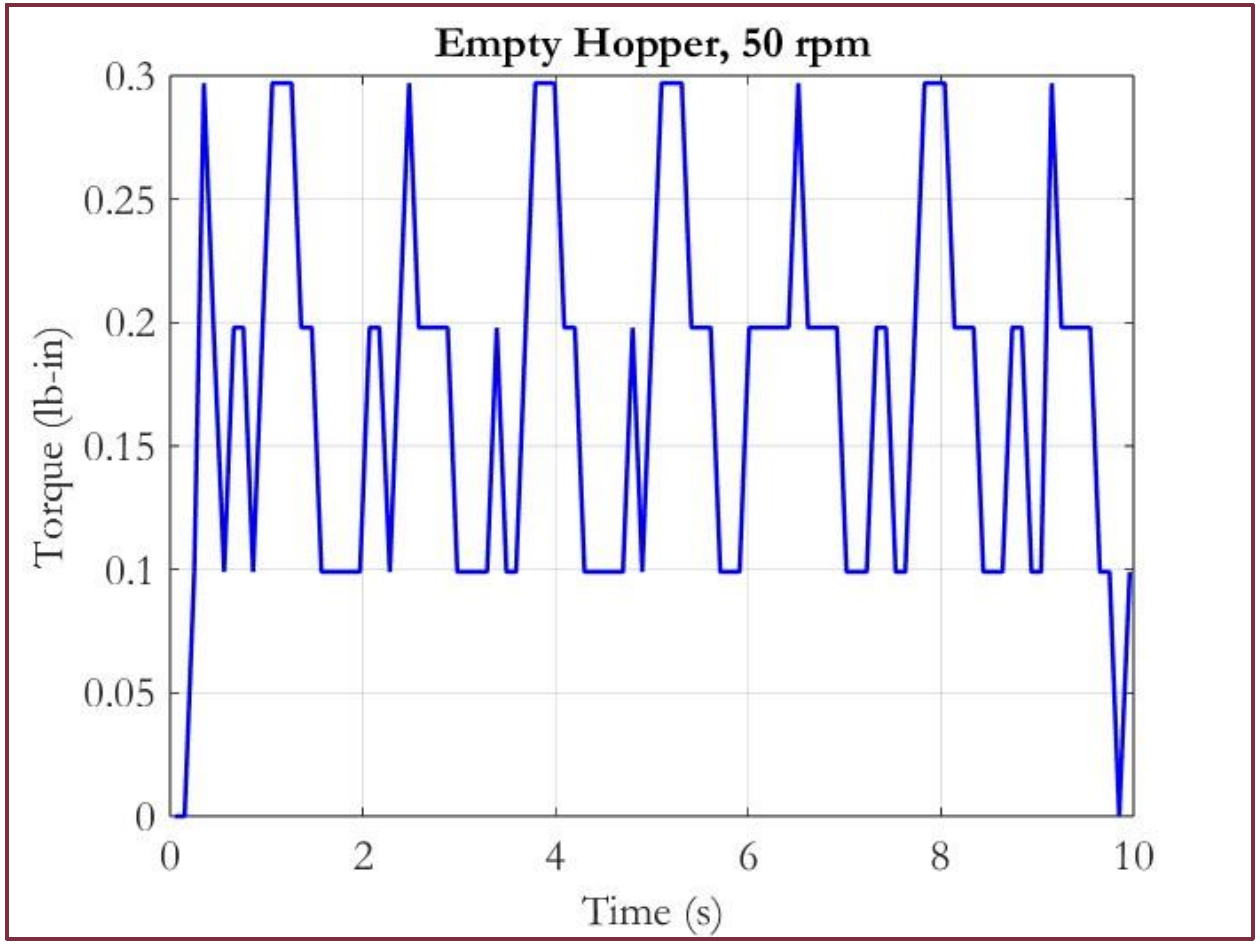


PARASITIC TORQUE

Characterization

To characterize the parasitic torque of our prototype 1 assembly, we tested it with no material in the hopper.

As shown, maximum torque was approximately 0.3 lb-in. Considering the full scale of 50 lb-in, this is less than 1% variation due to friction.



CALCULATION: VFD AND MOTOR PROPERTIES

Pros	Cons
No extra hardware needed	Depends on model accuracy
Real-time torque estimation	Less accurate at low speeds
Cost-effective	Sensitive to slip estimation errors
Can be very accurate with a good motor model	Electrical losses reduce accuracy
Integrates easily into control systems	Not as reliable as direct measurement (e.g., load cell)

MOTORS: STEPPER MOTOR VS DC MOTOR

Stepper Motor	DC Motor
Moves in discrete steps (fixed angles)	Spins continuously when powered
Provides precise position control without feedback	Speed controlled by voltage;position needs feedback(encoder)
Typically slower, but high torque at low speeds	Usually faster, less precise by itself
Requires a driver/controller to sequence steps	Simple to operate (just applyvoltage)
Common in 3D printers, CNC machines	Common in: fans, pumps, wheels

ENCLOSURE MATERIALS: ABS, PLA, PETG

Property	PLA	ABS	PETG
Tensile Strength (MPa)	40–65	30–45	40–55
Elastic Modulus (GPa)	3.0–3.6 (stiffest)	1.8–2.4	2.0–2.4
Impact Resistance	Low	High	Medium–High
Density (g/cm^3)	~1.24	~1.04–1.10	~1.27
Heat Resistance	Poor	Excellent	Moderate
Ease of Printing	Very easy	Difficult (warping)	Moderate (easy overall)
Layer Adhesion	Good	Moderate	Excellent
Surface Finish	Smooth/glossy	Matte	Glossy (may string)
Average Cost (/kg)	\$14–22	\$18–24	\$18–26

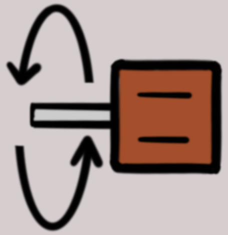
DATA COLLECTION

Signal Conditioning

DIGITAL FILTERS: Done after conversion with software. Typically use a low-pass filter or moving average.

ANALOG FILTERS: Done before conversion with electrical hardware usually as a low-pass filter to reduce noise.

PROTOTYPE 1 COMPONENTS

	Item	Description
	Stepper Motor	SureStep NEMA 34, 1288 oz-in (80.5 lb-in)
	Stepper Motor Driver	SureStep 6575
	Motor Power Supply	SureStep PSB48-480s, 48V
	Agitator	Custom, provided by Merrick
	Load cell	Adafruit, 5 kg
	Load cell amplifier	HX711, 24-bit ADC
	Data acquisition unit	Arduino UNO
	Data storage	Laptop with PuTTY software and USB connection

SHAFT COUPLER SPECIFICATIONS

Specification	Value
Material	Black oxide steel
Shaft diameter	½”
Maximum speed	3450 rpm
Maximum torque	235 in-lbs
Values per McMaster.com	

STEPPER MOTOR SPECIFICATIONS

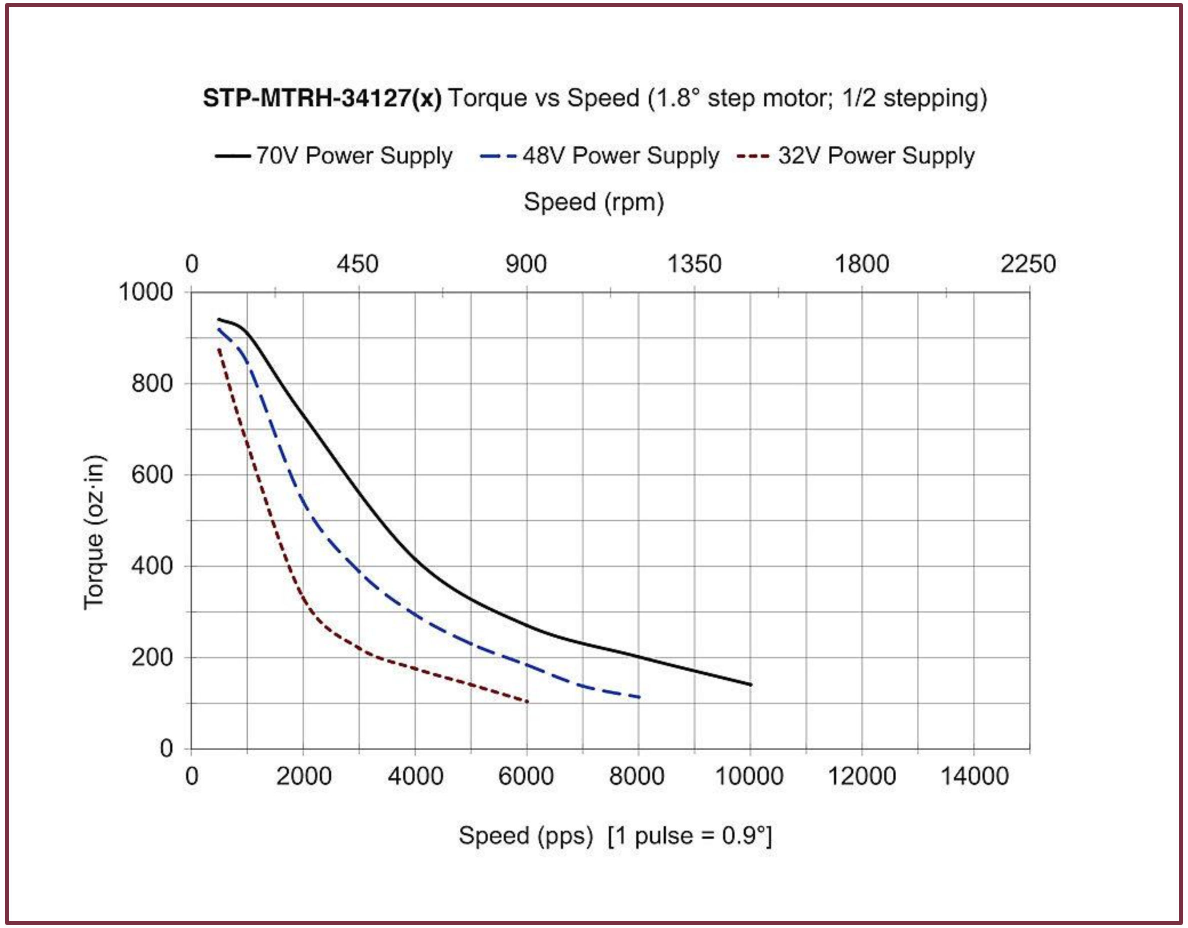
Holding torque: 1288 oz-in

1.8 degrees/step (200 steps/rev)

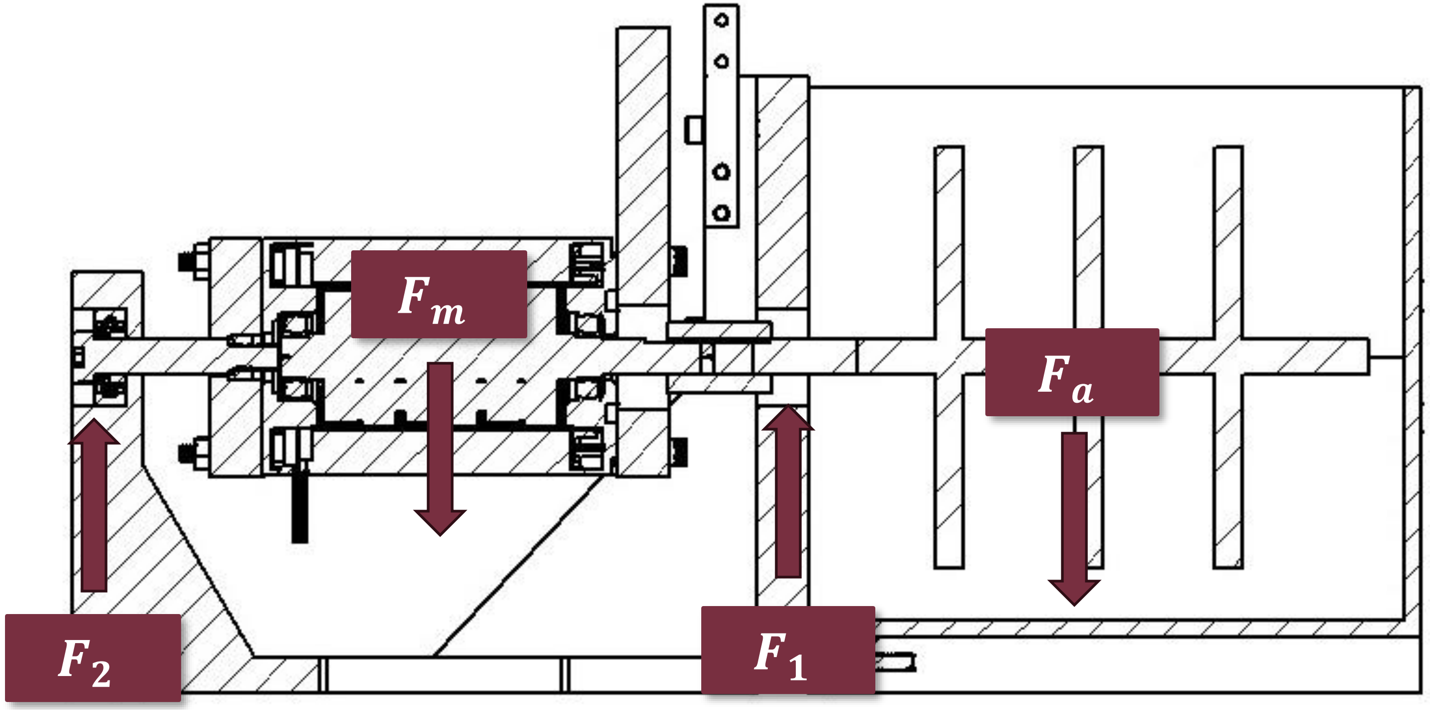
We are operating at 48V

@ 1000 pulses/sec, torque is approximately 850 oz-in

1 pulse = 1 half step = 0.9 deg



LOAD CALCULATION OF MOTOR ON BEARINGS



$$\sum M_1 = 0 = F_2(9.8\text{ in}) - F_m(4.9\text{ in}) + F_A(4\text{ in})$$
$$F_2 = 4\text{ lb}$$

$$\sum F_y = 0 = -F_A + F_1 + F_2 - F_m$$
$$F_1 = 7.6\text{ lb}$$

$$\sigma_1 = \frac{F_1}{ld} = \frac{7.6\text{ lb}}{(0.4375\text{ in})(0.5\text{ in})} = 35\text{ psi}$$

$$\sigma_2 = \frac{F_2}{ld} = \frac{4.0\text{ lb}}{(0.4375\text{ in})(0.5\text{ in})} = 18\text{ psi}$$

MORPHOLOGICAL CHART DECISONS

Modularity	0 means the concept does not allow for an interchangeable agitator or components | 5 means the concept allows for parts to easily be exchanged
Relatability	0 means the concept does not apply to commercial screw feeders | 5 means the concept closely relates to commercial screw feeders
Ease of Use	0 means the concept has a complicated set up and activation | 5 means the concept is easily set up and activated
Manufacturability	0 means the concept is not printable | 5 means the concept is printable and prints are done in one piece
Safety	0 means the concept is dangerous to users | 5 means the concept has ample stops in place in case of emergency and all components are encompassed
Cost	0 means the concepts dollar amount for manufacture would be excessive | 5 means the concept is effective in its use of funds