Cal Poly State University

ME Department

PRELIMINARY DESIGN REVIEW

MECHANICS DESKTOP LAB EQUIPMENT

Mechanic Maniacs

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ABSTRACT

Through the design process a final design was chosen and justified based off research, analysis, and design tools. The process leading to that design is shown in this document. The process and document shows that the best design for this test is one that incorporates an electric lead screw, an interchangeable testing block with a vice grip, and a friction hold top piece. This starts to narrow the additional design choices that will be needed to finalize the concept and build an initial prototype. During ideation large amount of different ideas that we could pursue were generated so many Pugh matrixes were created and considered for each component of this build. Through these matrixes of different component concepts we were able to generate a few strong ideas for each component. This led to 5 different initial full concept designs. Through the use of a weighted decision matrix this was then narrowed down into one final concept to be developed. This choice is very important as it allows us to start making decisions on more specific pieces. Knowing that an electric lead screw will be involved allows us to start looking at and deciding on motor choices. Finalizing the concept allows for a more focused design lens to be used going forward.

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1. INTRODUCTION

This document outlines the process and results of our ideation as well as the justifications of them and where we plan to go with the information. Our ideation process consisted initially of extensive research into other similar devices and products and through the use of brainstorming and pugh matrixes allowed us to settle on a few solid ideas that we could work with from there. The concept development section shows many of the ideas we considered and how we narrowed them down into our final designs. The concept design section describes our final design in detail including what we plan to make it out of as well as the methods by which it will operate. This section also contains our initial CAD model and sketches which will be used as the basis for our prototype. The concept justification section details the reasons why we believe our final design will be able to meet our customers' wants and needs well. Additionally, it details things we may see as an obstacle or issue going forward. Lastly with in future work we document and describe our plans for the design going forward.

Our scope has had a bit of a change since the original but not by much. Our current design has the ability to allow for many different blocks to be designed and used with our frame in the future even if we are unable to design them this year. Considering this device may be used for future projects to be improved upon, we thought it would be best to give a way that the device can be used for other tests in the future. We intend to now focus mainly on 3 tests. We are focusing on compression and tension while additionally designing the block for the bending test. Our design will ensure that there is room for extra tests as well as the electrical infrastructure to allow for other measurements. The project now expects the students to have a laptop to connect to so that they can save and view the data they collect.

The concept prototype we developed was a 3D printed model of our initial design to demonstrate the motion of the screws being able to move the crosshead of our design. As we move forward toward IDR and CDR we will be expanding upon our design and focus toward becing able to accomplish a single process for our upcoming structural prototype.

2. CONCEPT DEVELOPMENT

We started the design process by gathering all the needs and wants of all potential interested parties. Our two biggest groups were the students who would be using the lab and the professors who would be assigning the lab. A good design would serve both of these groups well. To help us gather these wants and needs we interviewed members of these groups. We asked a few students who had recently gone through the relevant classes what concepts they struggled with and that helped us to select which tests we wanted to use. This along with our own experiences with the class helped us to settle on using compression, torsion, bending, and tension. Interviews with professors also helped us to categorize what is good to have in a lab experiment.

We utilized a house of quality to plan out our needs and wants and plan out a way to evaluate the specifications. In the end we settled on cost, portability, accuracy, informativeness, Robustness, including a strain gage, Ease of manufacture, safety, variable outputs and inputs, and repeatability as our professor needs. As professor wants, we settled on battery power, having a live graph of outputs, and ease of repair. Upon further discussion with our sponsor and more thought about the problems that other power sources would have we decided that battery power was more of a need then a want. On the student needs we have helps understanding as our only need. We believe that if the lab helps in anyway with a students understanding then their needs will have been served fully. For the student wants we decided on ease of use and speed.

For our specifications we decided on measuring cost, weight, size, accuracy, safety, manufacturability, durability, ease of use, power use, repairability, noise, and speed of experiment. We used these values along with our functional decomposition to drive our ideation. We broke our design function into 5 main subfunctions. They were to reinforce topics covered in the lecture class, to introduce new concepts and equipment, to visually show effects of certain tests on materials, to provide an interactive lab experience, and to allow for labs to be run in rooms with limited space. These functions were further broken up and can be found in our functional decomposition which is in the appendix.

This is the foundation we used to start our ideation process. We started by individually listing possible ideas verbally that we could use for different parts of the device that we knew had to be included. We started with a list of ideas for the power source. Ideas included a central battery used for all the test units, a single battery per unit, wall power from an outlet, and solar panels. We quickly decided that our final idea would need to have a single battery per unit. Next we explored concepts that could be used to apply force to the test material. We discussed hand cranks, centripetal force, Calibrated weights, magnets, electric motors, hydraulics, and pneumatics. We decided that the best and most reliable idea would be either the electric motors or the calibrated weights. After this we tried to dump as many sketched ideas as we could out onto paper. The process of dumping all these ideas out slowly made us think more and more of alternative approaches which helps a lot with a design like this that can quickly become focused on one idea. Eventually we all settled on a few ideas that we thought had promise and with those created some concept models that could prove their viability. From this point we began to construct many pugh matrixes to measure how well the ideas compete with each other.

To start with we all developed one pugh matrix of separate functions. Our first pugh matrix evaluated the strengths of various methods of variable inputs in regards to our specific needs and wants. We evaluated a finite weight system, a crank, a manual torsion twist, A pressure vessel, and an electric lead screw. The results matched our original thoughts on the force system and the electric lead screw and finite weights tied and were well ahead of the rest. Additionally, we created a matrix to evaluate different base designs. These included a vice that would allow for blocks to be set in and tightened into place, a u shaped mounted piece of metal which would allow for thinner blocks to be screwed in, and a open cavity in the base which would allow for different test blocks to be slid into place and locked in. All three of these did well against many of the other designs so we took many of them into consideration when consolidating ideas. All three of these bases allows for many different blocks to be designed separably and still be used with the same testing frame we make. We then thought of ways in which the test material would be connected to the top of the frame. We considered threading the test material and connecting it with a bolt, using a pin to hold it in, using a tight fit and friction, and using a magnet with a magnetic test material. The results of the pugh matrix showed that a friction fit would likely be our best solution, so we took that into the final designs.

Final designs:

1) The first final idea involves a vice that holds different blocks of test material in the frame so that a lead screw can apply loads to it. It attaches to the top piece with a friction hold.

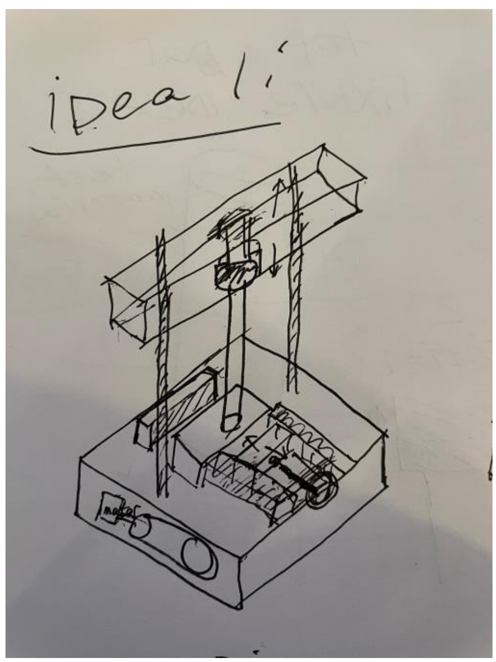


Figure 1: Idea 1

2) The second full concept also used a vice to hold blocks in place but the electric lead screw system is replaced with weights on the top platform. The platform is allowed to slide freely on the two rods and once placed upon the test material, weights can be loaded on to apply a load.

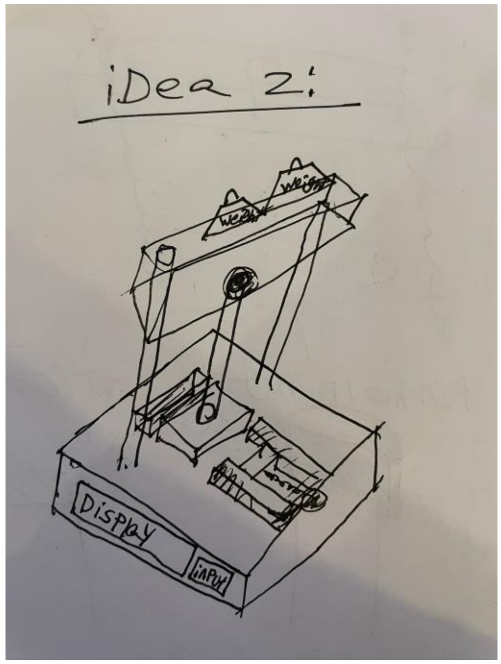


Figure 2: Idea 2

3) The third concept uses the electric lead screw to apply loads to the test material. The test material is now held in by the u-shaped metal piece in the base by screws that can be removed. This design allows the different test blocks to be much easy to store.

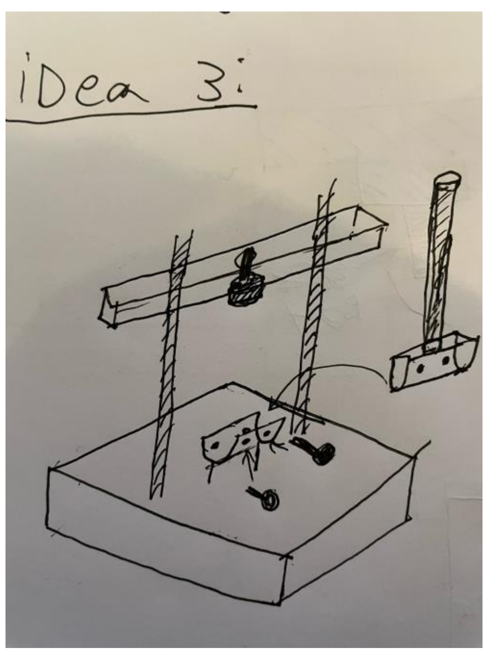


Figure 3: Idea 3

4) The fourth concept also has a lead screw to apply loads. The test block is held in place by sliding into a unique negative space in the base. A plate can then be screwed in to lock it in place.

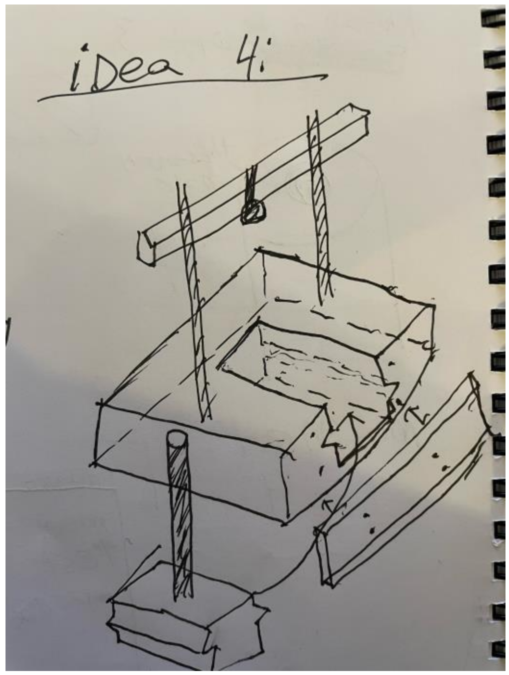


Figure 4: Idea 4

5) Concept 5 uses the vice to hold test blocks in place. The load is applied by a rack and pinion system.

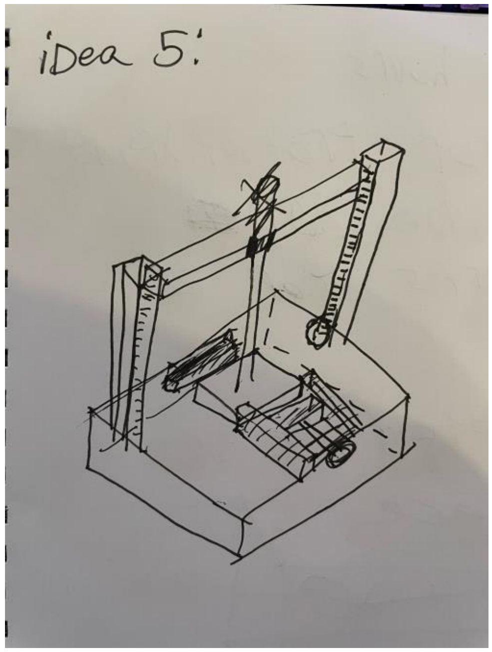
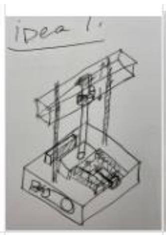


Figure 5: Idea 5

These 5 concepts were reviewed and evaluated through the use of the weighted decision matrix shown below.

Table 1: Weighted Matrix

						
	Weight	1	2	3	4	5
Cheap	3	3	4	3	3	4
Portable	4	3	3	5	2	3
Teaches Topics	5	4	4	3	4	4
good results	3	5	5	2	5	3
Battery Use	2	3	5	3	3	4
Ease of use	1	5	4	5	5	5
Robust	4	3	3	2	4	2
Variable I/O	3	5	2	5	5	5
Repeatable	2	5	5	5	5	4
Production Spee	2	3	4	3	2	3
Safety	5	5	3	5	4	3
Total	170	135	124	125	128	118

We consider idea 1 to be the strongest when evaluated by our own weighted criteria.

3. CONCEPT DESIGN

The chosen concept design was idea 1 which is better illustrated in Figure 6 which is a more detailed drawing of the design. To restate, the essence of the device is to maneuver the crosshead up and down in order to apply a load on the specimen underneath it. This load will allow for deformation of the specimen which can then be recorded and displayed in a manner that helps students to understand a particular concept. This deformation can be calculated from lead screw rotation or from the employment of strain gauges. The utilization of strain gauges would function to familiarize students with new equipment which is a part of our device's functional deposition which is found in Appendix C.

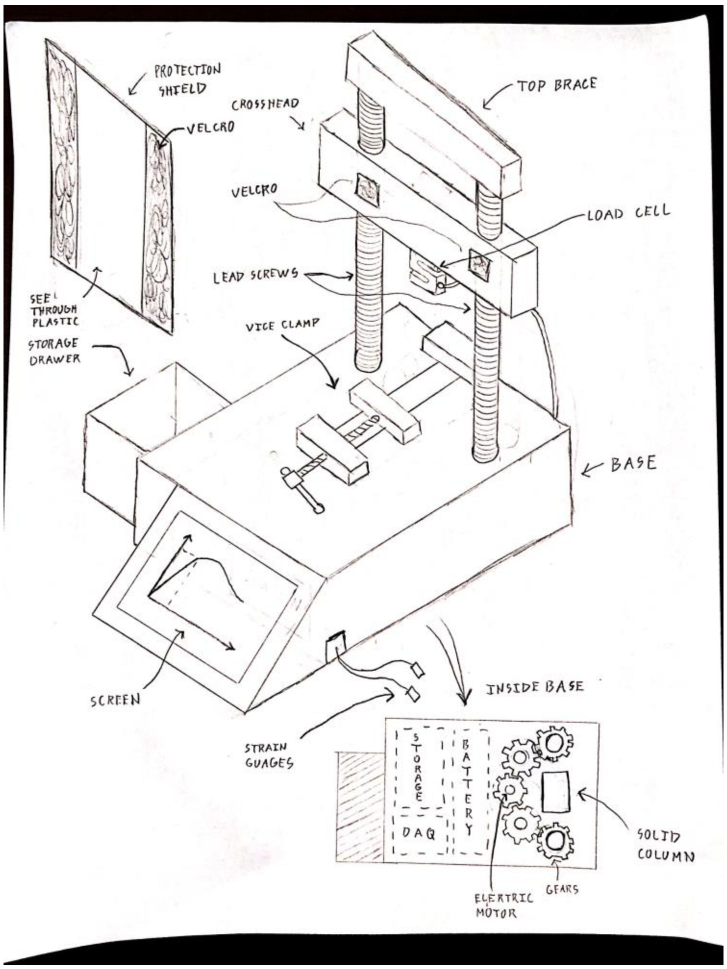


Figure 6: Concept Design Sketch

The device utilizes lead screws in order to drive the crosshead up and down with the help of lead screw nuts. These nuts are secured onto the crosshead using screws which ensure they do not spin and instead drive the crosshead travel. Underneath the crosshead an s-type load cell is screwed on which allows for the data accusation of the force being applied. Through a wire that runs to the base of the device data can be recorded and tracked, which is a key function found in Appendix C. A treaded hole is located on the bottom of the load cell in which different fixtures can be screwed on and off. This allows for variable loading conditions which functions to reinforce lecture concepts as this variety allows for several loading situations to be employed. This is a primary function of the device found in Appendix C.

A top brace holding ball bearings is placed on top of the lead screws to help stabilize the device by keeping the lead screws parallel to one another, which is essential if the device is to run efficiently. A vice is screwed on top of the base as it can secure the bottom portion of the specimen being tested. The vice was chosen as it allows for a plethora of different parts to be secured into the apparatus for testing and as such does not confine the scope of what professors may want to demonstrate in their labs. This also relates back to the function of reinforcing lecture content as it can not only allow for unique boundary conditions, but specimens as well which when situated in certain configurations demonstrate different mechanics of material concepts.

On the slope at the front of the apparatus a digital screen will be located which helps to illustrate data such as the stress vs. strain curve found in the previous Figure 6. This screen would ideally be touch screen enabling students to interact directly with certain variables of the apparatus in a manner that reinforces the "learning by doing" mentality which is core function found in Appendix C. Additionally, the data plotting in real time would allow students to visually grasp the effects of certain tests which is another core function in Appendix C. A protection shield would be an additional feature of this device that utilizes Velcro to attach the see-through plastic shield that permits students to observe the specimen with increased protection from potential projectiles hitting them.

Finally, underneath the base of the model lies space for the DAQ computer system, a storage drawer for fixtures, the battery and a gear series that allows one motor to drive both lead screw shafts. An illustration of the general layout is illustrated in the previous Figure 6. Then under the crosshead area, the base will have a wide column that ensures the rigidity of this area being put under load which also ensures the minimalist deflection possible. The bottom of this base will have a detachable floor which will allow for easy access to the components that are located within the base. The underside of this floor component would be covered with a high friction material such as rubber that would ensure that the device does not easily slide on a smooth table surface.

Our current progress towards the development of our design involves the concept prototype displayed in Figure 7. The point of this prototype is to ensure the functionality of the crosshead of the apparatus and its ability to apply forces in a manner that demonstrates that the device will remain stable when in action.

Figure 7: Concept Prototype

The current plan for the specifics of this device is for the footprint of the model to be roughly 12in x 14in x 15in. The base will have a height of roughly 2.5 in which it will be formed from aluminum sheet while the top brace will be machined from aluminum to be 11in x 2in x .5in. The crosshead will be roughly 11 in x 2.5in x 2 in and be machined from steel such as A830-1020 which is cheap and easy to manufacture. The lead screws are planned to be 1”-10 RH screws with a treaded length of about 12 in for which they will stand separated by 8 in. The lead nuts while be made from brass. The motor type that will be used to drive this machine will be a stepper motor that has a built-in locking feature. The cover of the device can be made out of sheet metal, but plastic cover could be a viable option as it is lighter and doesn’t need to be structurally strong as it just needs to act as a barrier between the electrical components and the user. Figure 8 presents this design intent below.

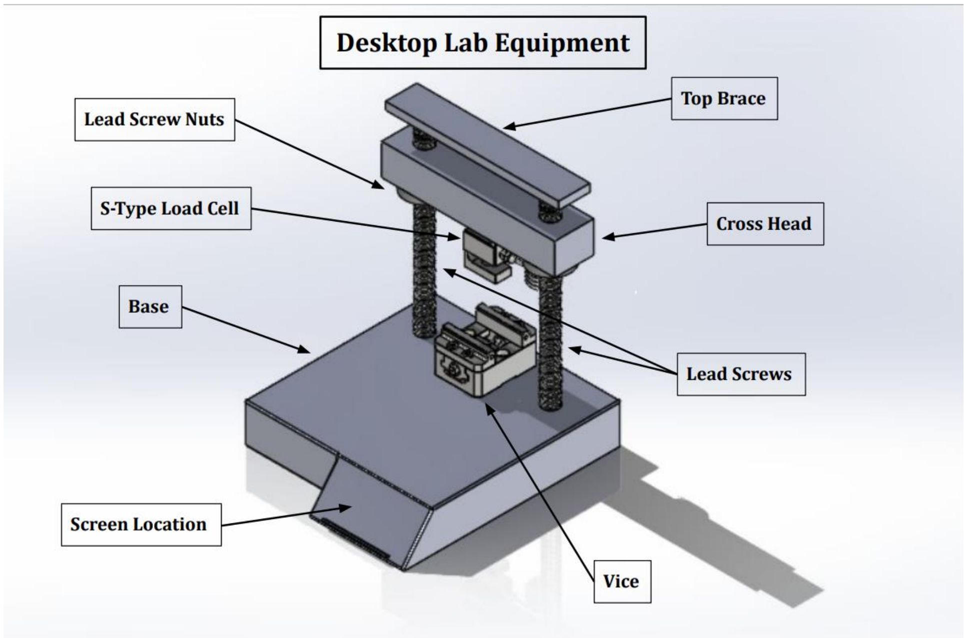


Figure 8: CAD Isometric

The portion of the project which is still unknown mainly involves the components that lie under the base of the apparatus. This includes the gear, shaft and bearing types for the transmission system along with the radial bearings used to counteract the axial load of the lead screws. The battery type and motor specifics are additional unknowns as prerequisite analysis is required to size them accordingly and ensure performance. Additionally, DAQ specifics are not known as further interviewing with Professor Ridgely will be required to gain a grasp on the modifications required for our set up. Fixture and specimen designs were not analyzed as they depend on apparatus specifics and as such can be investigated later while keeping them in mind.

We plan to use the olydaq 2 infrastructure to run the electronic control system and data acquisition system. The polydaq 2 has 4 strain gage ports with bridges that allow for strain gage data to be easily acquired. The polydaq 2 also has 4 voltage inputs which can be used to measure the output of the load cell. We plan to use 2 stepper motors that can be controlled via a motor controller. Both the motor and motor controller are from the company NEMA and should interface together well. The motor controller and polydaq must run off a battery with the polydaq 2 requiring 5-12 volts and the motor controller requiring 12 volts at 2 amps. We plan to have the device interface with student's laptops so that the acquired data can be displayed and collected off there. The microcontroller in the polydaq appears to run micropython and the graphic display on the laptop is programmed in python. The polydaq will need to take data at regular short intervals and send it to the computer. This data will be load cell data and strain gage data which needs to be formatted on the graphical interface. The polydaq will also need to be able to accept an input and tell the motor controller how far to turn to apply the appropriate force while constantly checking to ensure that the stepper motors have turned the correct amount. Any discrepancy in desired stepper motor movement and actual stepper motor movement must be corrected for to ensure accuracy.

4. CONCEPT JUSTIFICATION

The main goal of the project is to be able to demonstrate mechanics of materials topics in a manner that helps students to better understand the content, but several specifications are required to ensure the performance of the apparatus. This list of specifications can be illustrated in Appendix D. The current design of the model is to be able to apply and measure 1500 lbf from a given specimen as this amount seems to be around the capacity of our competitors such as that of Pasco's material tester being, "capable of measuring up to 7100 newtons (N) of force (1600 pounds)" [1]. With this as a starting point we were able to begin designing our device to meet the specifications mentioned earlier. The cost specification is difficult to prove this early on but looking at Table 2 below illustrates the pricing of components we have currently analyzed. This total of $250 might seem like a lot, but the components below encompass some of the more expensive parts being purchased so when considering it is only a fifth of the total budget range, it demonstrates how we are in range to meet our cost goal.

Table 2: Partial Cost list

Component	**Quantity**	**Cost**
Load Cell [2]	1	$150
Lead Screws Nuts [3]	2	$50.06
Lead Screws (36 in rod) [4]	1	$51.15

The weight of the apparatus should be within limit as the employment of aluminum in areas such as the top brace and base body should keep it light enough to make up for the heavier components such as the crosshead and lead screws. The volume specification is within limit as the current model has a volumetric footprint of 1.46 ft^3 which is within the 2 ft^3 threshold. The device is also able to cover at least 3 topics of mechanics as the ability to change the upper fixture and secure unique specimens in the bottom vice allows for the demonstration of compression, tension, bending, ect.

The accuracy of the device should be high due to the lead screw, base and crosshead design. The chosen lead screws have a pitch of .1 in as they are single start 1" -10 screws which means that each rotation of the lead screw by the motor will create short linear travel allowing for higher resolution on the specimen deflection values. The crosshead is designed to have minimal bending deflection which under a 1500 lbf load only deforms .00064 in, analysis is shown in Appendix D. The base has a solid column located under the crosshead which is designed to ensure the datum positioning of the specimen when under compression. While further calculations are required to prove the accuracy of the device, the choices above show steps have been taken to meet this requirement. The precision of the device can be ensured using a calibration block which zeroes the crosshead location after each test such as the one shown in Figure 9.

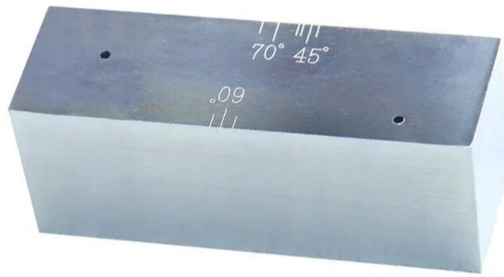


Figure 9: Calibration block [5]

The rest of the specifications are difficult to prove at this stage as further progress will be needed to ensure the speed of manufacturability, appearance and power use of the apparatus. Manufacturability estimates can be achieved by talking to shop tecs or IME professors to get their input. The general appearance of the device can be done with the use of surveys in which people rank how well they understand the device from inspecting it. Finally, power use can be calculated when other parameters specifics such as screen, motor and gear set up are all defined since they will all play a factor in battery life consumption.

Stepping away from specifications, specific design choices were made based on researched knowledge, preliminary calculations and engineering judgment. Lead screws were chosen as the linear actuators as they are used in similar products and are generally cheaper compared to other forms. Despite this being the current design, ball lead screws may be used instead as they have longer lifespans and are better able to carry higher loads but have the issue of costing more with the potential of being back driven. The general dimensions of the device were chosen as they felt both portable, but sizeable enough to allow students to engage with the apparatus itself. The motor choice was that of a stepper motor as they allow for rotations to be recorded and have models capable of handling the high loads required of it.

Structural integrity of the apparatus was investigated through preliminary calculations for the max loading conditions of device (1500 lbf) which are in Appendix D. The bolt that screws the load cell to the cross head was calculated to have a stress safety factor of ~1.5 once tightened to 80% of the bolts yield strength which proves the security of the load cell to the crosshead. The crosshead is extremely strong as it was more designed for deflection and thus has a stress factor of safety of 24. When looking at the lead screws they have a buckling force factor of safety of 16 while the stress factor of safety of the screws is ~2 under a super conservative assumption that only one line of threads is engaged. Additionally, the nut has a force factor of safety of ~6. These results illustrate how structurally sound the model is, but the reason for the preference for these high safety factors is due to our sponsor's desire to make the apparatus extremely durable.

The current challenge that we are facing is finding a way to easily incorporate torsion into the device as the vice prevents easy implementation of a motor drive that can placed underneath the base. While we have some ideas about the creation of a torsion motor fixture, we are unsure about the practicality of the implementation. Additional concerns include the ability of the device to handle a 3 ft drop which is written in the specifications made in Appendix D as the orientation of the fall could lead to deformations that impair the accuracy of the device. The manufacturing speed of the device may be more time consuming than what we had originally planned for them to be produced at due to us potentially underestimating the time required to configure the digital and mechanical aspects together.

5. FUTURE WORK

Looking at Appendix B which is the Gantt Chart, our plan for the future is to focus on creating a manufacturing plan, doing design analysis, and purchasing the necessary parts before we start building and testing our device. This will be done during the critical design review in order to stay on track for our project. In the future, we will eventually receive our yellow tags and begin building within winter and spring quarters. Testing will fully take place within the spring. Lastly, we will be writing out our final design review as we are finishing up our project.

For our early testing phase before the critical design review, some of our design analysis can be seen within Appendix E of our preliminary design review. Our current goal is to apply 1000 to 1500 lbs. of force upon our testing material. Within our calculations appendix, the free body diagrams are shown for each individual part being affected, and the proceeding calculations being accomplished within MATLAB. Lastly the factors of safety for the lead screws were calculated.

The planned purchases for now are to create the base out of aluminum and with the excess material we will be able to use as testing material. Additional purchases would be to buy A830-1020 steel crossheads, lead screws that are planned to be 1" -10 RH screws with a treaded length of about 12 in, ball screws, brass nuts to go along with the lead screw, ball bearings, a vice to fix material to the base of our design, load cells, and a possible touch screen monitor.

After completing the critical design review and structural prototype, we will move on to our final design. By then we should have all the purchased materials and will be beginning construction of the final testing apparatus. After completing the final build, we will proceed to test the design through the bending of certain testing materials. We will move forward by testing different kinds of material and see if our design holds up with the tests. Some of the materials we will be testing are aluminum, copper, 3D printed materials, and shape memory alloys. Then, we will test out other methods such as torsion, so we will be using our motor to create a torque on our testing material. If all goes well with the testing phase, we can move on to the final design review.

When it comes to safety, we have evaluated our concept design and created a design hazards checklist which is located Appendix F. The first hazard would be that our device does create pinch points due to the nature of the model. The plan of action is to add an additional safety element such as a see-through box that will be required to be put over the test area during use through a switch like mechanic. This added implementation would also ensure that users do not interact directly with large moving masses or projectiles which are other hazards on our list. Injury due to the device falling under gravity is another serious concern so the current plan is to vice the apparatus to the table so that it cannot tip or fall over. This concept could also help in stabilizing the machine while it is functioning. Other hazards include the electric system not being grounded and the potential dangers of having an energy storage system such as a battery. The plan to combat these hazards is to confine the electrical elements to mostly inside the base where they will be placed on electrically insulated surfaces and be blocked from physical access. This should prevent users being directly exposed to the dangers of these elements and if electrical wiring is required to leave the base, the voltage and current will be set at low values. Finally, the final hazard is that our device could be used in an unsafe manner. The only way we believe we can mitigate this risk is by spreading awareness about the dangers of the device and enforcing that safety rules be read to prevent unsafe actions from occurring.

6. CONCLUSION

All in all, this document describes the process and conclusions of our ideation and refinement of these ideas as well as the justifications for going along with these design decisions and how we plan to move forward with the criteria obtained. We began by developing our concept, which was done by considering who would be using our product, which was limited to professors and students. From this came our house of quality leading to our ideation phase. After determining all the possible ideas generated, we used Pugh matrices to narrow down the ideas to the best few and utilized a weighted decision matrix to find the concept that would be the overall best design. After determining the best design, we assessed the design choices which were made and looked over many possible options to find which would work best in our design. An example of this is where we decided on lead screws instead of other choices such as rack and pinion. Next, was the justification of our design choices, so similar to the design, but more in depth of how it will meet the key specifications and the preliminary design analysis. Lastly, this report includes the plans of how we will move forward with the project in depth until the CDR.

7. REFERENCES

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8. APPENDICIES

A. House of Quality

B. Gannet Chart

C. Function Decomposition

D. Specification Table

E. Calculations

F. Design Hazard Checklist

APPENDIX A: HOUSE OF QUALITY

Correlations	
Positive	+
Negative	–
No Correlation	

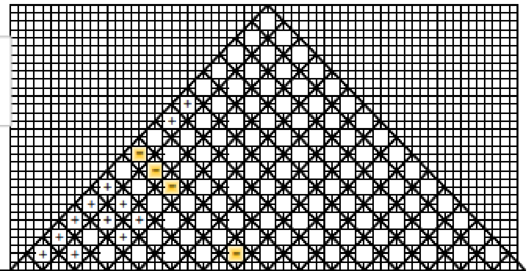
Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

QFD House of Quality

Project: Desktop Lab Equipment

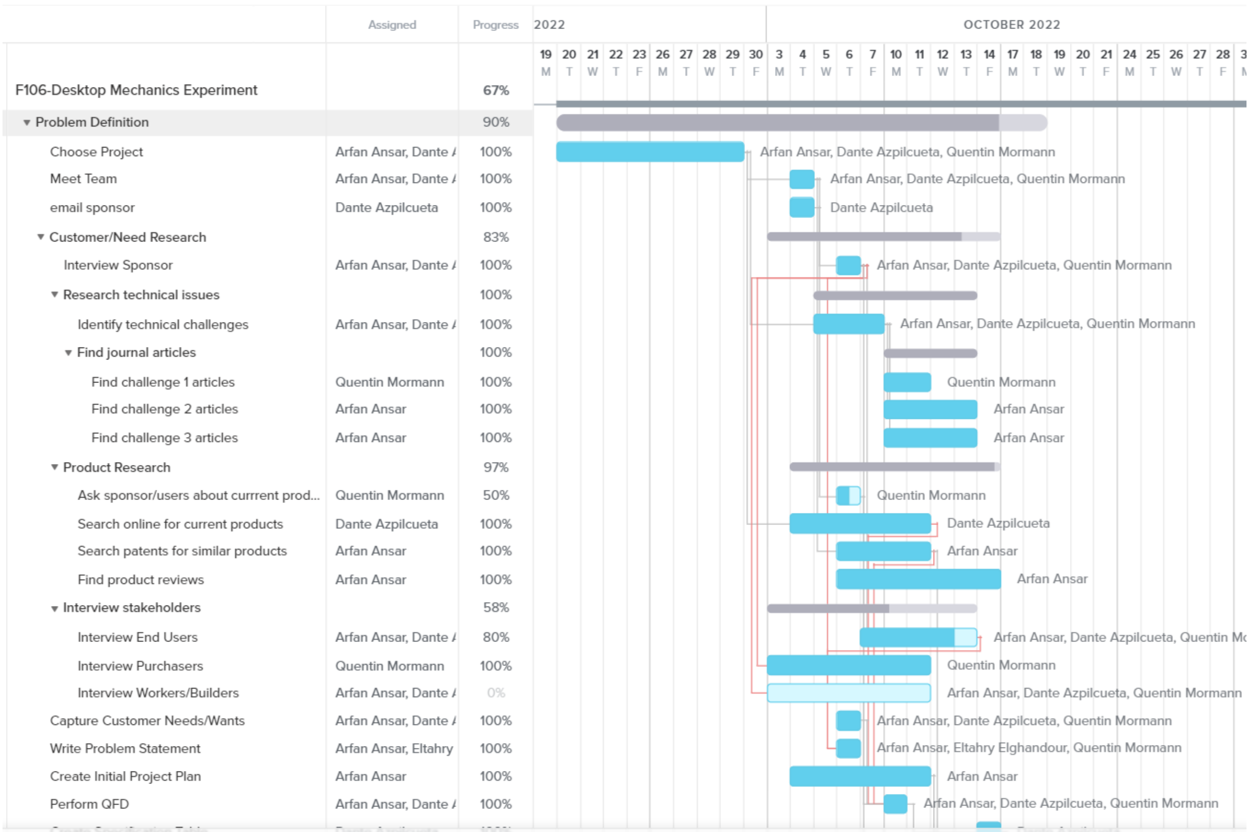
Revision Date: 10/11/22



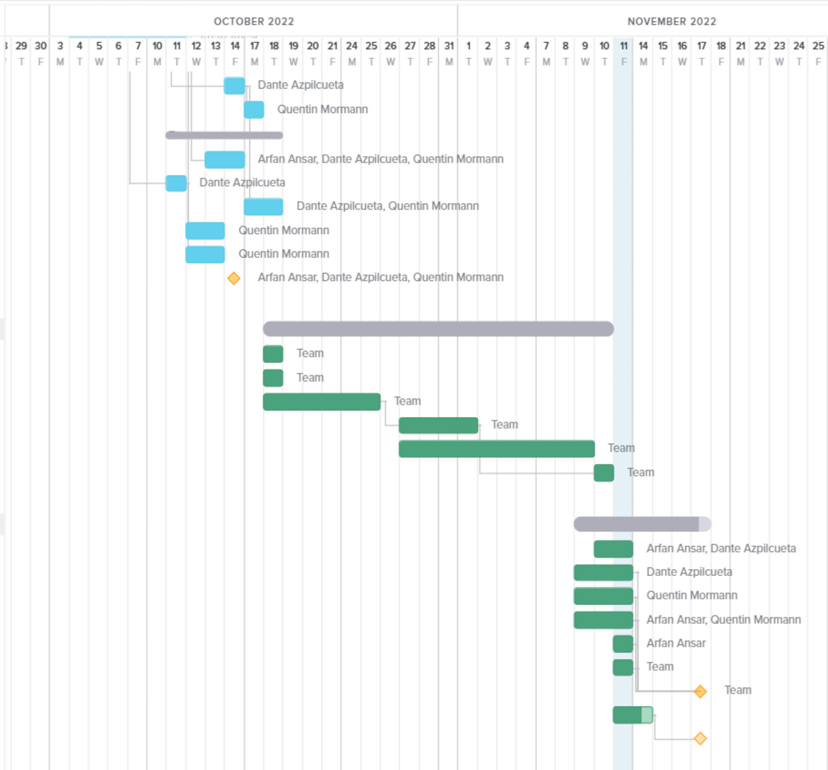
Row #	Weight Chart	Relative Weight	Students	Professors	Sponsor		Maximum Relationship	WHAT: Customer Requirements (Needs/Wants) \ HOW: Engineering Specifications (Tests)	Cost	Weight	Volume	Accuracy Test	Durability Test	Power Use	Concepts covered	Speed of Manufacturability	Safety Survey	Apperance Survey	Precision Test						Our Current Product	Competitor #1: Test Resources	Competitor #2: Instron	Competitor #3: ADMET	Competitor #4: Tesca	Row #
								Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16						
	WHO: Customers							Direction of Improvement	▼	▼	◇	◇	▲	▼	▲	▲	▲	◇	◇						NOW: Curr. Products					
1		4%	0	0	10		8	Cheap	●									●							5	2	1	1	3	1
2		12%	6	10	10		10	Portable		○	●		●	○		▽									5	3	1	3	4	2
3		14%	10	10	10		10	Teaches topcis			○	▽			●										5	4	3	3	4	3
4		7%	5	7	3		7	Achieve good results	○			●													4	4	5	5	4	4
5		7%	4	3	8		3	Battery Power		○				●											5	2	1	2	3	5
6		3%	0	4	4		4	Production Speed	▽		●					●									4	1	1	1	1	6
7		9%	3	8	9		8	Robust	○	○	○		●			▽									2	3	5	4	3	7
8		8%	10	3	3		3	Easy of Use							▽			●	▽						4	3	2	2	3	8
9		8%	0	10	10		10	Include strain guage				○			●										5	1	1	1	1	9
10		13%	10	8	10		8	Safe for students		●	○			▽			●								5	5	5	5	5	10
11		12%	8	9	9		9	Visible Inputs and Outputs			○	▽			○			●							4	2	5	4	3	11
12		3%	0	5	3		5	Repeatable	▽										●						4	3	5	4	2	12
13		0%																												13
14		0%																												14
15		0%																												15
16		0%																												16

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
HOW MUCH: Target Values	$500	< 35lbs	5ft^3	within 5% of expected	Must not break from 3 foot impact	> 6 hours	3 topics covered	1/week	No moderate or severe injuries	Simple	All data points are within 5% of					
Max Relationship	10	5	8	5	7	4	10	7	9	6	9					
Technical Importance Rating	87.48	199.3	277.4	114.4	182.4	108.2	243.4	49.33	118.4	217.3	37.97	0	0	0	0	0
Relative Weight	5%	12%	17%	7%	11%	7%	15%	3%	7%	13%	2%	0%	0%	0%	0%	0%
Curr. Products: Our Current Product	5	5	5	5	5	5	5	5	5	4	5					
Competitor #1: Test Resources	4	3	4	3	3	1	1	1	5	4	5					
Competitor #2: Instron	1	1	1	5	3	1	2	1	5	2	5					
Competitor #3: ADMET	1	3	3	5	3	1	2	1	5	2	5					
Competitor #4: Tesca	4	3	3	3	3	1	1	1	5	5	5					
Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

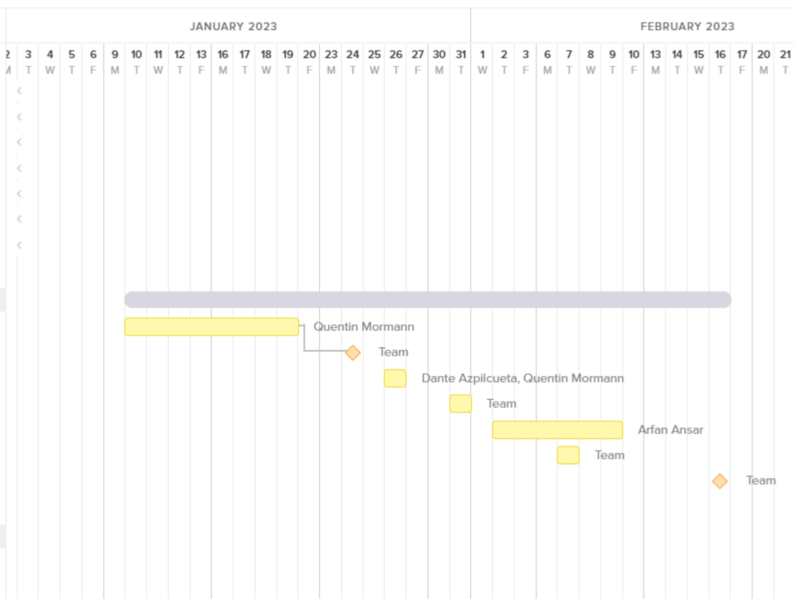
APPENDIX B: GANTT CHART



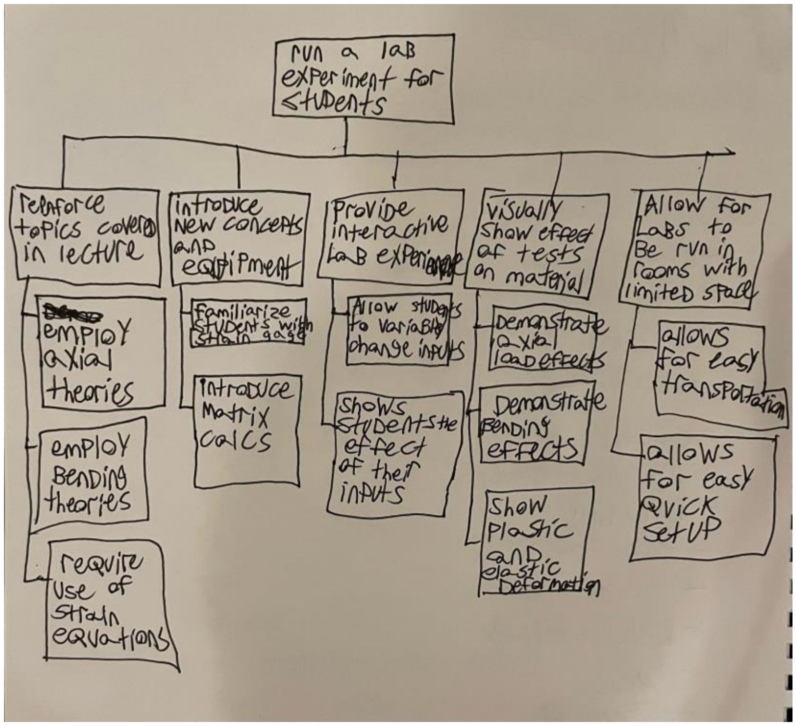
Task	Assigned	Progress
Create Initial Project Plan	Arfan Ansar	100%
Perform QFD	Arfan Ansar, Dante A	100%
Create Specification Table	Dante Azpilcueta	100%
Write Specification Descriptions	Quentin Mormann	100%
▾ Write Scope of Work		100%
Write Background	Arfan Ansar, Dante A	100%
Write Scope	Dante Azpilcueta	100%
Write Objectives	Dante Azpilcueta, Q	100%
Write Proj Mgt	Quentin Mormann	100%
Write Intro/Concl	Quentin Mormann	100%
Scope of Work (SOW)	Arfan Ansar, Dante A	☑
▾ Concept Generation & Selection		100%
Scope of Work Grading	Team	100%
Functional Decomposition	Team	100%
Ideation	Team	100%
Idea Refinement & Selection	Team	100%
Pugh Matrix	Team	100%
Build Concept Prototype	Team	100%
▾ Write Preliminary Design Review		91%
Write Introduction/Conclusion	Arfan Ansar, Dante A	100%
Write Concept Development	Dante Azpilcueta	100%
Write Concept Design	Quentin Mormann	100%
Write Concept Justification	Arfan Ansar, Quentin	100%
Write Future Work	Arfan Ansar	100%
Add References and Appendices	Team	100%
Preliminary Design Review (PDR)	Team	☑
PDR Presentation Slides		70%
PDR Presentation		☐



Task	Assigned	Progress
Write Concept Development	Dante Azpilcueta	100%
Write Concept Design	Quentin Mormann	100%
Write Concept Justification	Arfan Ansar, Quentin	100%
Write Future Work	Arfan Ansar	100%
Add References and Appendices	Team	100%
Preliminary Design Review (PDR)	Team	☑
PDR Presentation Slides		70%
PDR Presentation		☐
▾ Detailed Design & Analysis		0%
Design Analysis	Quentin Mormann	0%
Interim Design Review (IDR)	Team	☐
CAD/Part Selection	Dante Azpilcueta, Q	0%
Structural Prototype Build Day	Team	0%
Manufacturing Plan	Arfan Ansar	0%
Purchasing Plan	Team	0%
Critical Design Review (CDR)	Team	☐
▾ Manufacturing		0%
Manuf & Test Review	Dante Azpilcueta	☐
Verification Prototype Sign-Off	Quentin Mormann	☐



APPENDIX C: FUNCTIONAL DECOMPOSITION



APPENDIX D: SPECIFICATION TABLE

Spec. #	Specification Description	Requirement or Target (units)	Tolerance	Risk *	Compliance**
1	Cost	1500 ($ per unit)	Max	L	A
2	Weight	35 (lbs)	Max	L	A,I
3	Volume	1.25x1.25x1.5 (ft^3)	Max	L	T
4	Accuracy Test	Expected Value	±5%	M	T
5	Durability Test	No damage from 3 foot drop	Min	H	T
6	Power Use	6 hour battery life	Min	M	T
7	Concepts covered	3 topics covered	Min	L	T,A
8	Speed of Manufacturability	1/week	Min	M	S
9	Safety Survey	Minor Injury	Max	H	I
10	Appearance Survey	Simplistic/Easy to Use	Semi-Complicated	M	I
11	Precision Test	Output Value	±5%	M	T

* Risk of meeting specification: (H) High, (M) Medium, (L) Low

** Compliance Methods: (A) Analysis, (I) Inspection, (S) Similar to Existing, (T) Test

APPENDIX E: CALCULATIONS

Desktop Lab Equipment

```
clc;
clear;
```

Table of Contents

Given

The current goal is to be able to apply 1000 lbf on a material

```
F = 1500; % Force on material
```

General model of the design is shown below,

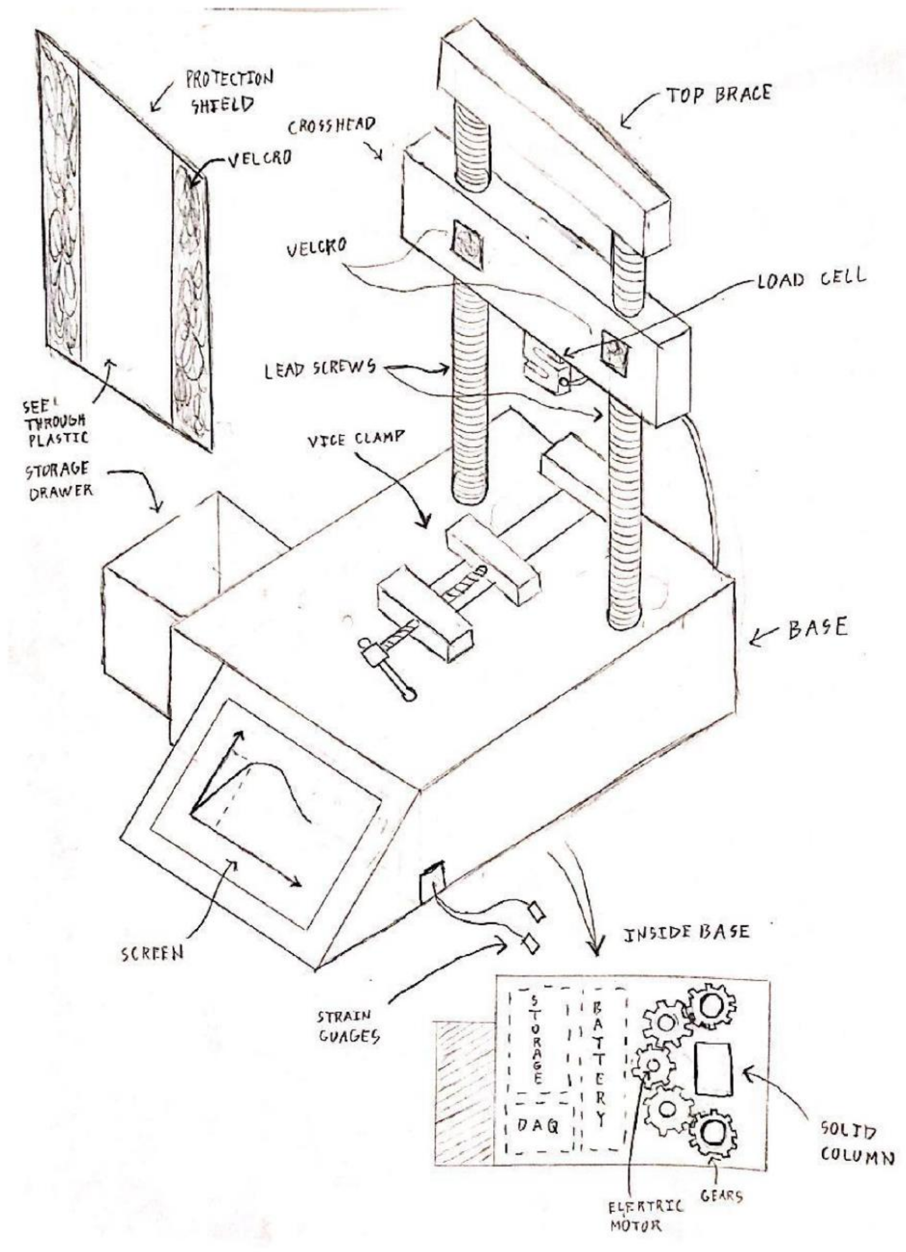


Figure 1: Lab Equipment Design

Find

Analyze the sizing of components that would be needed in order to handle the given loading force

Assumptions

1) Symmetric design

2) Neglect the strength of the base

3) Bolt Preload to 80% of Yield

4) Simply Supported Crosshead

5) Neglect Crosshead Transverse Shear

References

1) Shigley's Mechanical Engineering Design by Richard Budynas

2) Load Cell

https://www.scaledynasty.com/1500-lb-S-Type-Beam-Load-Cell-p/op-312-1500.htm

3) Lead Screw

https://www.helixlinear.com/Products/Lead-Screws/Lead-Screws-and-Acme-Screws/Acme-Screw-1-2--10-RH-SS-~1%E2%81%842%22-%2010%20RH%20SS

4) Lead Screw Nut

https://www.nookindustries.com/products/screws/acme-screw/110000/

https://www.roton.com/product/acme-bronze-threaded-mount-nut-right-90140/

5) ASME Thread Sheet

https://www.roton.com/products/acme-lead-screws-nuts/engineering-data/

6) 1020 Steel

https://www.tritonalloysinc.com/aisi-1020-steel-plate.html

Analysis

Figure 2 below is the initial loading conditions

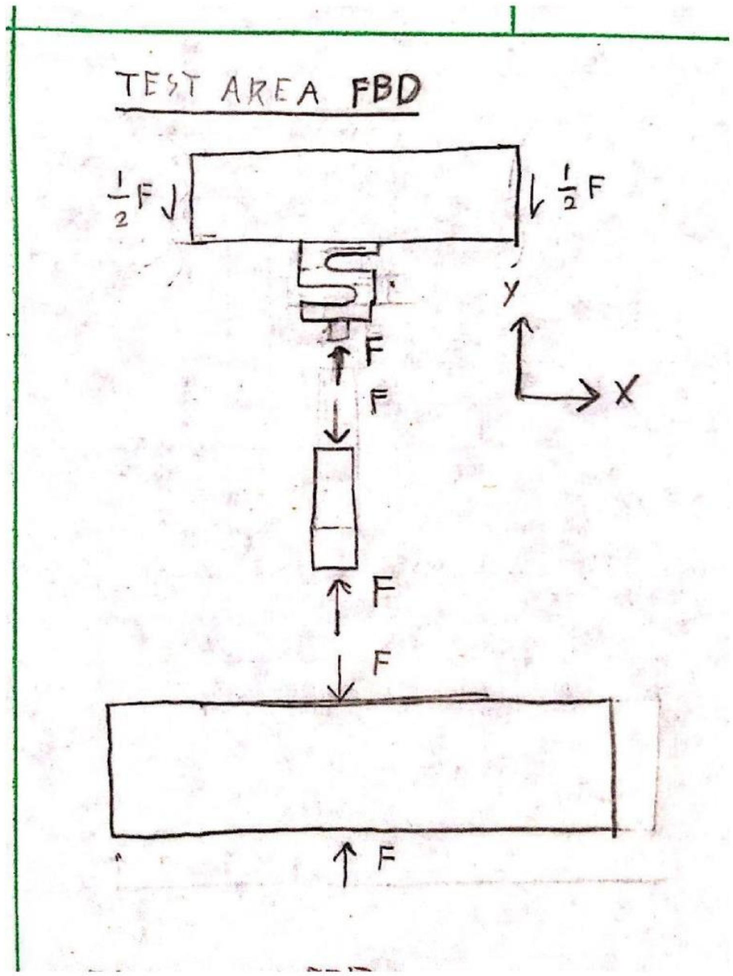


Figure 2: Initial Loading

For the sake of this analysis the base will not be examined as the current goal is to have a solid column support beneath the loading area which shouldn't make it an important area to preform analysis on for this degree of loading. So, the cross head portion will first be analyzed.

Cross Head

Load Cell

A load cell must first be determined which can handle this planned load:

Krol Warner 1,500lbf Load Cell (Ref 2):

```
h_lc = 2.5;     % Height of Load Cell [in]
d_lc = 1;  % Depth of Load Cell [in]
w_lc = 2;     % Width of Load Cell [in]

%% Mounting Holes Are 1/2in x 20UNF
D_lc = .5;     % Threaded Hole Diameter [in]
```

Nut and Bolt Analysis

Choose a bolt:

SAE Grade 4 Bolt

```
A_t = .1419;              % Tensile Stress Area of Bolt [in^2] (Ref 1: Table
8-2)
Sy_b = 100E3;             % Yield Strength of Bolt [psi] (Ref 1: Table 8-9)
```

Parameters

```
J = (pi/2)*((D_lc/2)^4);   % Bolt Polar Moment [in^4]
```

Bolt preload

```
syms Fi
K = .2;                    % Torque Factor - Zinc-Plated (Ref 1: Table 8-15)
Tor = (K*Fi*D_lc);         % Wrench Torque (Ref 1: Eqn. 8-27) [lbf-in]
Sigma_b = Fi/A_t;          % Normal Stress [psi]
Shear_b = Tor*(D_lc/2)/J;  % Shear Stress [psi]
```

Assume: Bolt Preload of 80% Yield

```
eqn = .8*Sy_b == (1/sqrt(2))*sqrt(2*(Sigma_b^2)+ 6*(Shear_b^2)); % Von-Mises
Equation
```

Solve Bolt Preload and Wrench Torque

```
Fi = abs(vpasolve(eqn,Fi));    % Bolt Preload [lbf]
Tor = (K*Fi*D_lc);             % Wrench Torque [lbf-in]
```

Max Bolt Force

```
FM_b = F + Fi; % Total Force in Bolt [lbf]
```

Check for Yielding of Bolt under Total Force

```
nb_y = Sy_b/(FM_b/A_t) % Bolt Yielding Safety Factor [-]
```

```
nb_y =
1.4903113210069771962102810696668
```

Cross Head Bar

An FBD of the Crosshead is below

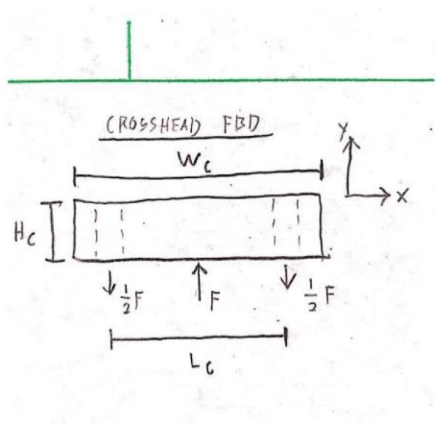


Figure 2: Crosshead FBD

Dimensional Parameters

```
Hc = 2;   % Crosshead Height [in]
Dc = 2.5; % Crosshead Depth [in]
Lc = 8;   % Lead Screw Distance Apart [in]
I_c = (1/12)*(Dc*(Hc^3)); % Crosshead Moment of Inertia [in^4]
A_c = Hc*Dc; % Crosshead Cross Sectional Area [in^2]
```

Material Parameters (AISI 1020)

```
Sy_c = 29.7E3; % Yield Strength of Steel [psi] (Ref 6)
E_c = 30E6;    % Elastic Modulus [psi] (Ref 1: Table A-5)
```

Stress Analysis

```
SigmaC_b = ((F*(Lc/2))*(Hc/2)/I_c) % Max Bending Stress [psi]
```

```
SigmaC_b = 3.6000e+03
```

```
TauC_s = (3*(.5*F))/(2*A_c)        % Max Shear Stress For Rectangular Beam (Ref 1: Eqn. 3-34) [psi]
```

```
TauC_s = 225
```

Factor of Safey (Neglect Transverse Shear)

```
nc_y = Sy_c/(SigmaC_b) % Beam Safety Factor [-]
```

```
nc_y = 8.2500
```

Deflection Analysis (Assume: Simply Supported)

```
DeltaC = -(F*(Lc^3))/(24*I_c*E_c) % Beam Deflection (Ref 1: Table A-9) [in]
```

```
DeltaC = -6.4000e-04
```

Lead Screw & Nut

An FBD of the Lead Screw is below

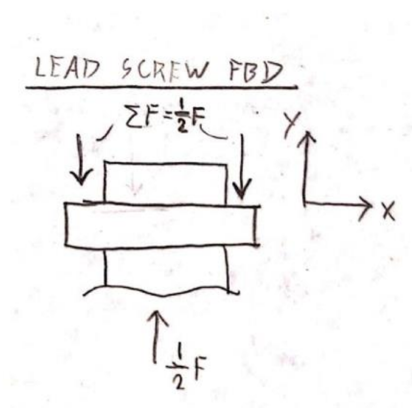


Figure 3: Lead Screw FBD

Specifications

Load per Lead Screw

```
F_ls = .5*F
```

```
F_ls = 750
```

Parameters (Ref. 3 and 4)

```
D_ls = 1;  % Lead Screw Major Diameter [in]
P_ls = .1;  % Lead Screw Pitch [in]
l = .1;     % Lead Screw Lead [-]
Trating_ln = .078; % Lead Nut Torque to Raise [(in/lb)/lb]
Frating_ln = 5000; % Lead Nut Dynamic Load Rating [lbf]
```

Stainless Steel 303 Strength (Ref.1)

```
Sy_ls = 35E3; % Lead Screw Yield Strength [psi] (Ref 1: Table A-22)
E_ls = 27.6E6; % Lead Screw Elastic Modulus [psi] (Ref 1: Table A-5)
```

Calculated Parameters

```
Dr_ls = 0.856;     % Lead Screw Minor Diameter [in] (Ref 4)
nt_ls = 1;         % Number of Engaged Teeth [-] (Assume: 1 for max stress)
A_ls = pi*(Dr_ls/2)^2;         % Lead Screw Area [in^2]
I_ls = (1/4)*pi*((Dr_ls/2)^4); % Lead Screw Moment of Inertia [in^4]
k_ls = sqrt(I_ls/A_ls);        % Lead Screw Radius of Gyration [in]
```

Torque applied

```
T_lc = F_ls*Trating_ln; % Torque for required axial force [lbf]
```

Stress Analysis

Stress Analysis on the outer radius of screw body

```
 sigx_lc = (6*F_ls)/(pi*Dr_ls*nt_ls*P_ls); % Bending Stress [psi] (Ref 1: Eqn. 8-11)
 sigy_lc = -(4*F_ls)/(pi*(Dr_ls^2));       % Axial Stress [psi] (Ref 1: Eqn. 8-8)
 sigz_lc = 0;  % No out of plane stress
 tauxy_lc = 0; % No out of plane stress
 tauyz_lc = (16*T_lc)/(pi*(Dr_ls^3));          % Normal Shear Stress [lbf] (Ref 1: Eqn. 8-7)
 tauzx_lc = (4*T_lc)/(pi*(Dr_ls^2)*nt_ls*P_ls); % Tangental Shear Stress [lbf] (Ref 1: Eqn. 8-12)
```

Von Mises

```
 sigma_ls = (1/sqrt(2))*((sigx_lc-sigy_lc)^2 + (sigy_lc-sigz_lc)^2 + (sigz_lc-sigx_lc)^2 + 6*(tauxy_lc^2 + tauyz_lc^2 + tauzx_lc^2))^(1/2); % [psi]
```

Buckling Analysis

Buckling (Look at worst case scenario central loading)

```
 L_ls = 12;  % Lead Screw Length [in]
 C_ls = .25; % End Condtion Fixed-Free [-] (Ref 1: Table 4-2)
 lk_o = sqrt((2*(pi^2)*C_ls*E_ls)/Sy_ls) % Slenderness Ratio Set Point [-]
```

```
lk_o = 62.3814
```

```
 lk_a = L_ls/k_ls % Actual Slenderness Ratio [-]
```

```
lk_a = 56.0748
```

If lk_a is less then lk_o use Johnson Equation

```
 FcrJ_ls = A_ls*(Sy_ls - (((Sy_ls*L_ls)/(2*pi*k_ls))^2)*(1/(C_ls*E_ls))) % Critical Buckling load [lbf] (Ref 1: Eqn. 4-48)
```

```
FcrJ_ls = 1.2004e+04
```

If lk_a is greater then lk_o use Euler Equation

```
 FcrE_ls = (A_ls*(C_ls*(pi^2)*E_ls))/(lk_a^2) % Critical Buckling load [lbf] (Ref 1: Eqn. 4-44)
```

```
FcrE_ls = 1.2464e+04
```

Factor of Safety

```
nls_y = Sy_ls/sigma_ls % Lead Screw Factor of Safety [-]
```

```
nls_y = 1.9966
```

```
nlsn = Frating_ln/F_ls    % Lead Screw Nut Force Factor of Safety [-]
```

```
nlsn = 6.6667
```

```
nls_b = FcrJ_ls/F_ls      % Lead Screw Buckling Factor of Safety [-]
```

```
nls_b = 16.0060
```

APPENDIX F: DESIGN HAZARD CHECKLIST

PDR Design Hazard Checklist **<u>Desktop Lab Equipment, Group F106</u>**

Y	N	
x		1. Will any part of the design create hazardous revolving, reciprocating, running, shearing, punching, pressing, squeezing, drawing, cutting, rolling, mixing or similar action, including pinch points and sheer points?
	x	2. Can any part of the design undergo high accelerations/decelerations?
x		3. Will the system have any large moving masses or large forces?
x		4. Will the system produce a projectile?
x		5. Would it be possible for the system to fall under gravity creating injury?
	x	6. Will a user be exposed to overhanging weights as part of the design?
	x	7. Will the system have any sharp edges?
x		8. Will any part of the electrical systems not be grounded?
	x	9. Will there be any large batteries or electrical voltage in the system above 40 V?
x		10. Will there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids?
	x	11. Will there be any explosive or flammable liquids, gases, or dust fuel as part of the system?
	x	12. Will the user of the design be required to exert any abnormal effort or physical posture during the use of the design?
	x	13. Will there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
	x	14. Can the system generate high levels of noise?
	x	15. Will the device/system be exposed to extreme environmental conditions such as fog, humidity, cold, high temperatures, etc?
x		16. Is it possible for the system to be used in an unsafe manner?
	x	17. Will there be any other potential hazards not listed above? If yes, please explain on reverse.

For any "Y" responses, on the reverse side add:
(1) a complete description of the hazard,
(2) the corrective action(s) you plan to take to protect the user, and
(3) a date by which the planned actions will be completed.

PDR Design Hazard Checklist **Desktop Lab Equipment, Group F106**

Description of Hazard	Planned Corrective Action	Planned Date	Actual Date
1. The device is designed to squeeze and pull on specimen materials in way that pinch points would occur at the base of the material near the vice or even between the crosshead and the top brace of the apparatus.	The housing will be designed to not allow the user to interact with the points of danger during use	2/16/22	
3. Large forces will be applied to the test material during tests	The user will be blocked off from direct contact during use of the test.	2/16/22	
4. Projectiles may be produced by the test material by the applied forces.	A safety screen will be added to our final design to prevent any possible projectiles from injuring anyone.	2/16/22	
5. The device is designed for use on a standard desk and as such is prone to falling off the desk.	A material with a high coefficient of friction will be set into the bottom of the device where it interacts with the desk making it much harder to slide off the desk. A vice clamp may be used to secure it to the table.	2/16/22	
8. A battery will be used that does not have a ground and as such will have a floating ground instead of an earth ground	The user will be unable to touch or interact with any piece of electrical wiring and the housing will be electrically insulated	2/16/22	

10. A battery will be used in the device to supply power.	The battery will be stored within the base of the testing apparatus so no student will be able to interact with it.	2/16/22	
16. The device can be used in many unsafe manners such as putting random objects in the test area or not securing the device properly.	Safety section in lab manual where the device is discussed. During Expo an acrylic/plastic box will be placed over the device to prevent any direct interaction with the apparatus.	2/16/22	