A rat model for studying hazards in industrial power tool operation

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ABSTRACT

Many repetitive motion injuries in the industrial workplace can be attributed to repetitive usage of power hand tools which cause dangerous hand loads. Animal studies can be conducted to lead to conclusions about the physiology of these injuries. Our goal for this project is to create a device that can model power hand tool usage using lab rats. The key component of our design that differs from the current design being used for these studies is that it will provide a reaction force to the pulling force of the rat. The force of the rat must be measurable in order for the device to sense when to provide a reaction force. Our proposed solution is a linear actuator in combination with a force sensor. The force sensor will determine when the rat is or is not pulling on the handle, and the linear actuator will be responsible for the reaction force.

PROBLEM STATEMENT

Background

- Client (Prof. Radwin) and team at Temple University are interested in effects of long term repetitive motion injuries
- Aim to quantify repetitive power tool operation injuries on rat model
- Need adjustable device which provides reaction forces to rat arm eventually leading repetitive motion injury

Current Design

- Current model being used by researchers at Temple is the Vulintis Mototrak model
- Automated, quantitative measures of forelimb function in rats
- Model is static; no reaction force

Figure 1: This is a picture of the Vulintis Mototrak model being used by Temple University.

DESIGN CRITERIA

- New design must fit inside cage-mounted device of similar dimensions to the Vulintis Mototrak
- New device needs to at least account for the rats average reach force of 1.44N and their average reach duration of 0.05 secs
- Design must provide an adjustable reaction force that should ramp up to 1.2N to the rat pulling on the handle
- Design should be able to sense when rat begins pulling on handle and when it lets go
- Rat must hold on to the handle for at least 0.05s for food to be released

Figure 2: As shown in the picture above, the handlebar will be 2.5cm from the slot in the cage wall, distance from window to handlebar: 1.5cm

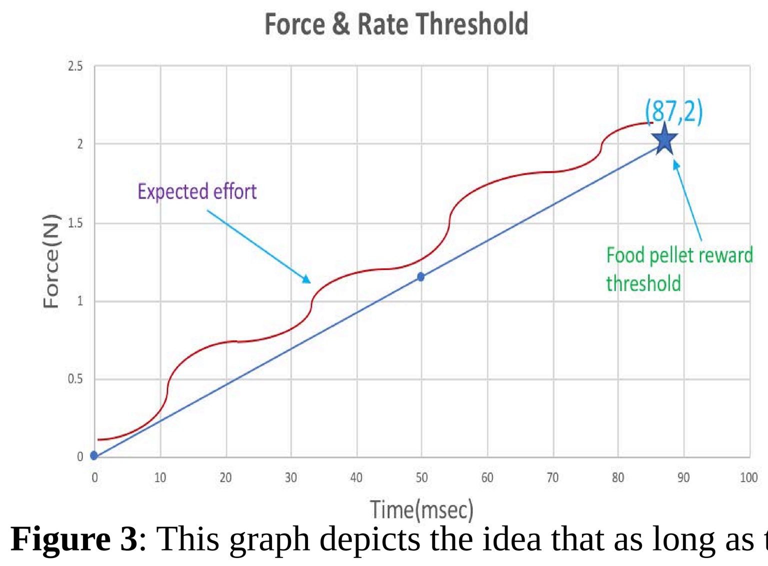

Figure 3: This graph depicts the idea that as long as the rat applies more force than the reference force over time (shown above by the blue line) the linear actuator will continue to pull on the rat's arm until the target force is reached.

PROGRESS

Preliminary Design

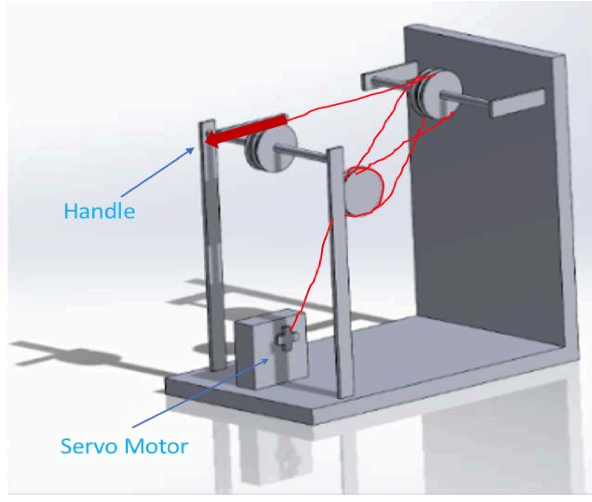

Figure 4: This is a diagram of our pulley model.

- Displacement is controlled by a servo motor
- Servo motor is controlled by Arduino microcontroller
- 4 to 1 block and tackle system to increase the speed of the servo motor displacement

- Too many moving parts
- String is slightly elastic

Final Design

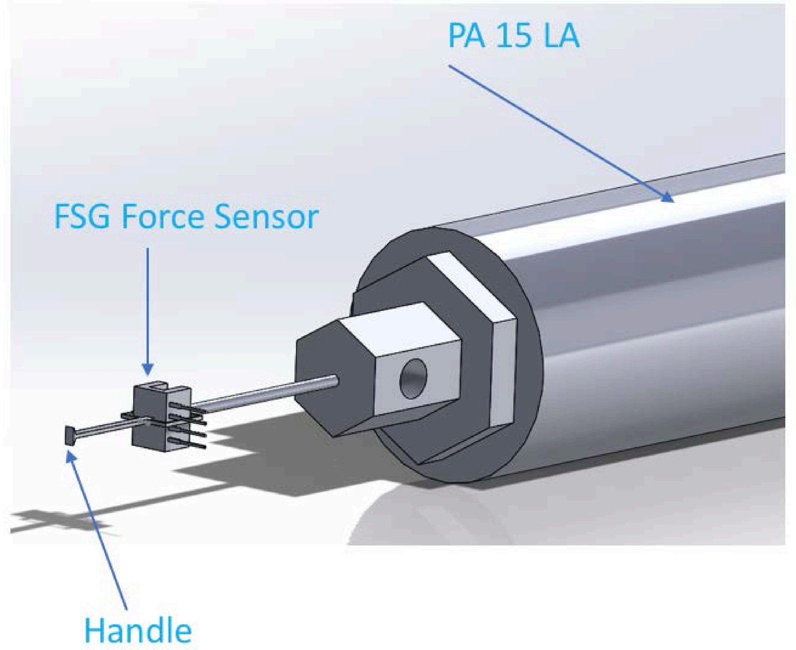

Figure 5: The model shown above is a representation of the final design.

Components

- PA15 - Linear Actuator
- Arduino Microcontroller
- 12V Power Supply
- MOSFET H-Bridge
- FSG Series Force Sensor

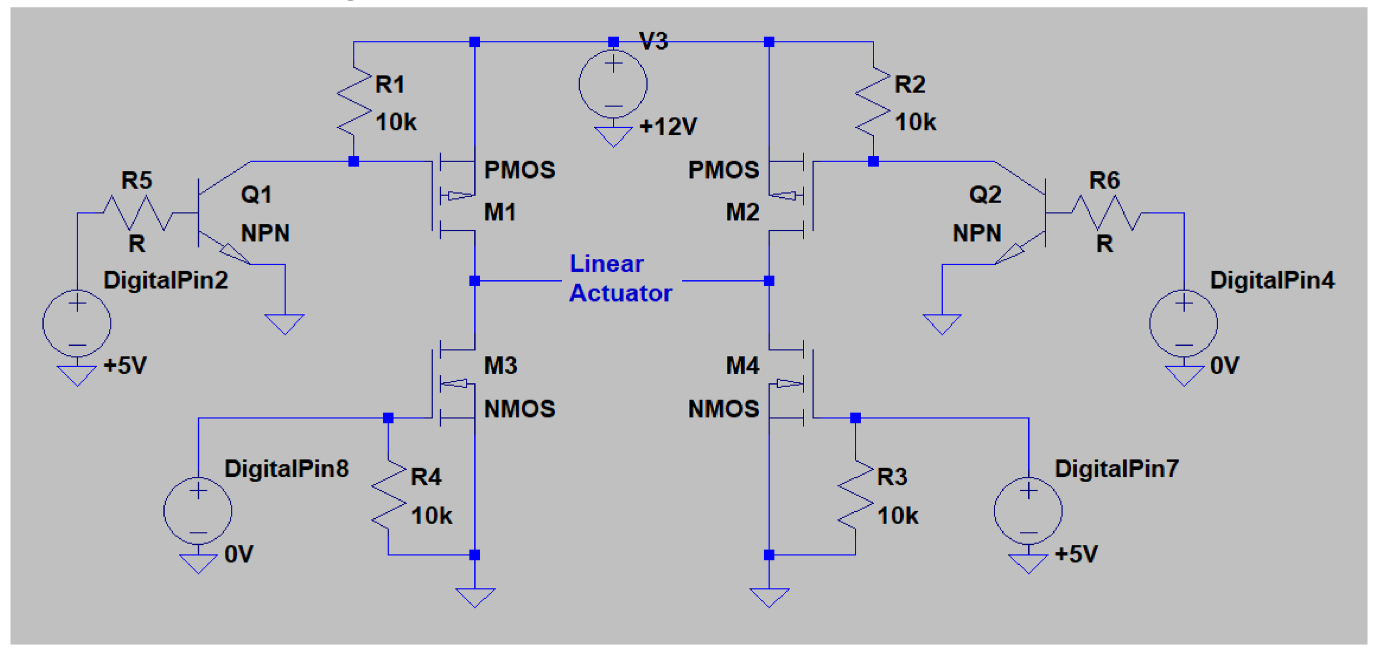

Figure 6: This LTSpice generated MOSFET H-Brige is a representation of the polarity controlling circuit used in our final design.

RESULTS

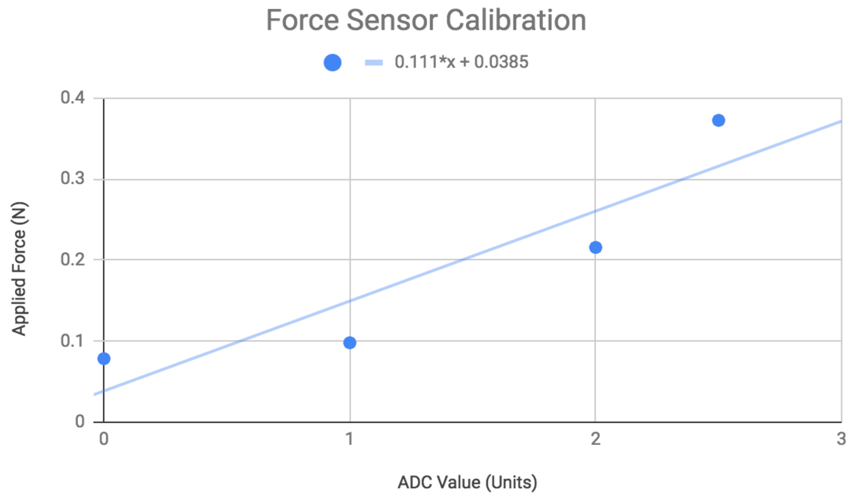

Figure 7: This FSG Force Sensor Calibration plot was used to find an equation to convert ADC values to force values in newtons.

- Measurement of continuously applied rat load
- Force sensor controlled polarity mimicking repetitive jerking reaction forces

DISCUSSION

Implications

We were able to move the linear actuator at the average speed

- The client can now model repetitive hand motion injuries on a majority of the rats
- The experiment being run by the client can possibly be scaled up to show the effects of repetitive hand motion injuries on humans

We were able to detect the forces being applied to the rat's arm

- This allows us to know when the rat is holding on to the handle, which would tell us if the rat is actually holding on to the handle for the full duration of the time and holding on with enough force.

Limitations

Our design lacks both adjustability and applied force ramp time.; we are also unsure of whether or not the design will fit into the cage-mounted device

- This means the researchers will be unable to test the affects of having forces applied over different speeds, so they can't test different impulses
- This would also make it more difficult for the researchers to train the rats

FUTURE WORK

Adjustability

- Allow for variable force and speed ramp
- Incorporate PWM for speed control
- Attach to the Vulintus Mototrak model

Figure 10: This is an image of the linear actuator that could be used in the future. This actuator has a force sensing element integrated into it and costs around 3-5 thousand dollars. This linear actuator also meets the requirements for the client's speed and design specifications.

CONCLUSION

We were able to set a force threshold to sense when the rat is holding on to the handle as well as to sense how much force the rat is holding onto the handle with. We were able to set a polarity across the linear actuator power supply to extend and retract the shaft. This was done using the force detected by the FSG force sensor. The design currently is not adjustable and doesn't have an applied force ramp time.

REFERENCES

S. A. Hays, N. Khodaparast, A. M. Sloan, D. R. Hulsey, M. Pantoja, A. D. Ruiz, M. P. Kilgard, and R. L. Rennaker, "The isometric pull task: A novel automated method for quantifying forelimb force generation in rats," *Journal of Neuroscience Methods*, vol. 212, no. 2, pp. 329–337, 2013.
J.-H. Lin, R. G. Radwin, and T. G. Richard, "Handle Dynamics Predictions for Selected Power Hand Tool Applications," *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 45, no. 4, pp. 645–656, 2003.
V. S. Massicotte, N. Frara, M. Y. Harris, M. Amin, C. K. Wade, S. N. Popoff, and M. F. Barbe, "Prolonged performance of a high repetition low force task induces bone adaptation in young adult rats, but loss in mature rats," *Experimental Gerontology*, vol. 72, pp. 204–217, 2015.
Vulintus - Mototrak. [Online]. Available: http://www.vulintus.com/mototrak/. [Accessed: 05-Oct-2018].