Power Tool Operation- Rat Model

BME 200/300

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Client:

Professor Radwin - Industrial and Systems Engineering

Advisor:

Professor Tompkins - Biomedical Engineering

Team Members:

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Abstract

Long term muscle fatigue and damage due to large eccentric loadings on the muscles are commonplace for industrial workers. Though this problem is widespread it is not well understood as human testing is of course not possible. Our project proposes to use rat models to better understand this injury by creating a device which provides eccentric loadings to the rats, forcing the rat to exert a certain amount of force with its arm before being rewarded with a treat. Our design will use a linear actuator to provide the eccentric loading and will be coupled with the Vulintis Motortrak in order to gage the forces the rat is applying.

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Introduction

This device is meant to model power tool operation by humans, through the use of a rat model. This device is necessary because the repetitive motion due to long term, consistent use of power tool operation can lead to muscle weakness, fatigue, and joint problems. This device will allow the researchers to test these effects on rats, in order to gain an understanding of the effects on the limbs of rats, which is the first step in understanding the effects on humans. The findings of the research that is conducted on the rat model will benefit the workers in industries that are using power tools consistently. Further, this may contribute to newer and better safety regulations, and better technology. Current guidelines require power tools to be fitted with guards and safety switches (Hand and Power Tools), and new guidelines for new safety mechanisms may be researched once there is more information available.

Power hand tool operation in factories and service facilities, including threaded fastener tools (i.e. screwdrivers and nut drivers), present hazardous hand loads resulting in repetitive motion injuries. The rapidly rising impulse loads transmitted to the hands while operating tools often produce stressful eccentric muscle contractions, which exceed the operator's capacity to hold the tool stationary and stretch muscle fibers and tendons, resulting in chronic injuries due to repetitive loading. The objective of this research is to conduct animal studies leading to an understanding of the pathophysiology associated with repetitive tool operation. This project proposes to develop a device that contains a handle that a rat can be trained to pull which initiates a controlled rapid impulse force in the opposite direction that results in eccentric muscle contractions in the rat's arms, simulating repetitive power hand tool operation. The investigators intend to train rats to repetitively pull on the handle using sufficient force to activate a motor that pulls the rat hand in the opposite direction in order to receive a food pellet. The device will need to fit inside a cage-mounted device of similar dimensions that currently controls passive pull force.

The most reported occupational illnesses in the US are physical work-related injuries. In an attempt to find a solution to this challenge, researchers at Temple University are investigating work related musculoskeletal disorders (WMSDs). Their research involves the study of repetitive strain injuries with rat models. In a study, rats ankle muscles were analyzed during steady-speed jumping and when the rats were startled. We are concerned in this case in the results when the rats were startled, as it is more related to what we are working on). When the rats were startled, forces reached as high 175% of the maximal elicited isometric were reached. The peaks in force always occurred while the muscles were being stretched (A. A. Biewener).

The research team currently runs its investigations using the Vulintis Mototrak. The Mototrak is a complete system that includes a cage, controller, behavior module, pellet dispenser, auto positioner, and the MotoTrack software. Utilizing this system rats were trained and data was collected to determine the average reach force and the average reach duration. The average reach force was 1.44N and the average reach duration was 0.05 secs.

Fig 1. Vulintis Motortrak

Our client, Dr. Radwin, works in industrial and systems engineering as well as biomedical engineering at the University. His interests in research deals with injuries that occur in the industrial workplace.

Our design must provide a reaction force to a rat pulling on a handle. The reaction force should be adjustable. It also must be able to sense when the rat begins pulling on the handle, and when it let's go. If the rat does not hold on to the handle for at least 0.05 seconds, food will not be released for the rat.

Preliminary Designs

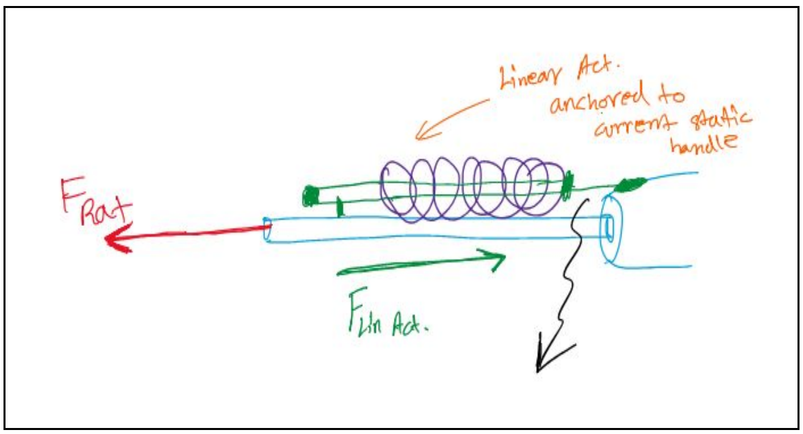

Fig 2. Linear Actuator Design utilizes linear actuator to provide resistive force to the rat

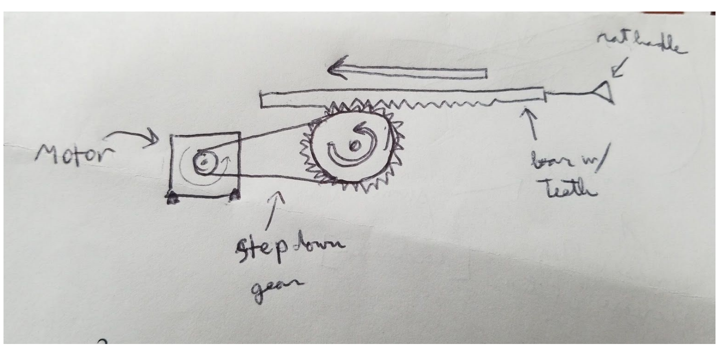

Fig 3. Motor and Gear Design uses high torque ratio gear system to achieve more fine movements and apply the resistive force to the rat.

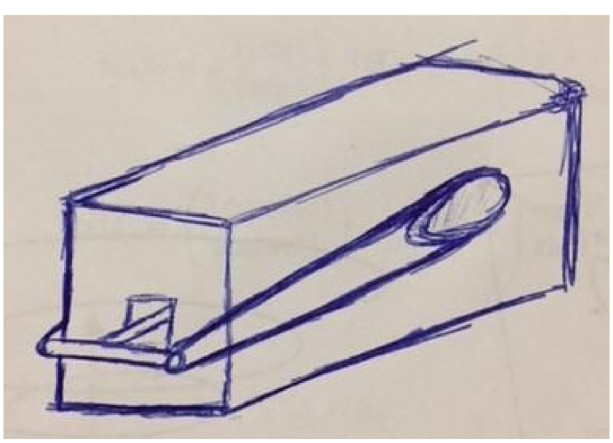

Fig 4. Rubber Band Design uses bands of various tensions to apply varying resistive loads on the rat.

Figure 2 is our linear actuator design. It includes a linear actuator that is wired to an arduino through a MOSFET. The arduino will monitor the force being applied on the handle connected to the actuator. When the rat begins to pull on the handle, the linear actuator will begin to move in the opposite direction of the rats pull. After the rat has applied the target force, the arduino will sense this and food will be released to the rat. The arduino will help with being able to select the reaction forces applied to the rats pull.

Figure 3 is our gear and motor design. It is powered by a motor which rotates a gear. The gear is attached to a linear toothed rail piece, translating the gears angular motion into linear motion. The linear piece provides the reaction force to the rats pull. The motor would be controlled by a arduino, which would be able to sense when to start the motor, as well as how much of a reaction force to provide.

Figure 4 is our rubber band design. There are two rubber bands that are latched onto either side of a small box, and onto either side of the handle. The handle is then attached to a sensor inside of the box. When the rat pulls on the handle, the rubber band automatically provides the reaction force. The sensor would then serve the purpose of determining that the rat was pulling on the handle, and how long the rat had been pulling on the handle.

Preliminary Design Evaluation

Design:	Rubber Band		Motor & Gear		Linear Actuator	
Adjustability(25)	3/5	15	4/5	20	5/5	25
Consistency(25)	2/5	10	3/5	15	5/5	25
Ease of Integration(20)	3.5/5	14	3/5	12	2/5	8
Feasibility(25)	3.5/5	17.5	3/5	15	2/5	10
Cost(5)	5/5	5	3/5	3	3/5	3
Total 100	**61.5**		**65**		**71**	

Our five criteria are adjustability, consistency, ease of integration, feasibility, and cost. Our linear actuator design received the highest score for adjustability because it will be controlled by a microcontroller which will allow the client to control the force through their software. Our linear actuator also received our highest score for consistency because we believe that it will provide the most constant force on the rat over multiple trials. Our rubber band design received the highest scores for ease of integration, feasibility and cost. The rubber band design is our easiest to integrate because it will probably require no programming, unlike the linear actuator and motor and gear designs, and will only require putting a rubber band into place. The rubber band design is our most feasible design because we will most easily be able to complete this design and produce this product in the given time period with our resources. All we would need to produce this design are rubber bands. The rubber band design is also the most cost efficient, as rubber bands are much cheaper than purchasing a linear actuator or a motor and gears.

Proposed Final Design

The design we've chosen is the Linear Actuator. The linear actuator design received the highest scores on two of our categories that were weighted the most in our design matrix. The linear actuator received the highest scores in both adjustability and consistency which were each weighted 25, and are what we consider two of the most important criteria going into this design process. Although the rubber band design received higher scores in more categories these categories were weighted less. The rubber design may be cost efficient but our budget is large enough that it can easily take the linear actuator design.

Fabrication/Development Process

Materials

1. Linear actuator
2. Stepper Motor
3. Arduino
4. MOSFET

5. Springs of various spring constants
6. Small screw clamps to attach linear actuator to rat handle

Methods

1. Secure two small screw clamps to the linear actuator about 2 cm apart (screw clamps will be used to attach linear actuator to the rat handle
2. Wire linear actuator through the MOSFET to the PWM pinout of the arduino
3. Wire the Vulintis Mototrak into analog input pin of arduino so that we can read the force data which the current model is measuring
4. Code outline for arduino:
    a. Calculate force being applied by linear actuator using voltage input
    b. Compare this value with force being measured in Vulintis Mototrak
    c. If net force positive continue building resistive force until desired force is achieved
        i. If desired force is achieved release treat and return solenoid to origin
    d. Else if net force less than or equal to 0 reset solenoid to origin

Testing

1. Apply resistive force to linear actuator using spring to model rat arm and ensure that a net force is in fact being registered
2. Do the same test with a force gauge to ensure that the correct force value is being registered
3. Test whether solenoid stops and returns to zero strain when net force is not sufficient by interrupting resistive force application

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Appendix

A rat model for studying hazards in industrial power tool operation, Team PT GKG

Product Design Specification (PDS)

Client: Prof. Radwin

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Client requirements

- Needs a device which provides an opposing force to the rat's pull
- Forces applied to the rats as well as reach duration should be able to be changed by the researcher
- Opposing force should begin immediately once the rat begins to pull on the handle
- The rat must retain it's grasp on the handle for a given amount of time in order to receive it's food (the food should not fall out immediately once the rat pulls on the handle).
  - Threshold reach duration from 25 to 250ms (rat should hold on until force threshold is reached

Function

Power hand tool operation in factories and service facilities, including threaded fastener tools (i.e. screwdrivers and nut drivers), present hazardous hand loads resulting in repetitive motion injuries. The rapidly rising impulse loads transmitted to the hands while operating tools often produce stressful eccentric muscle contractions, which exceed the operator's capacity to hold the tool stationary and stretch muscle fibers and tendons, resulting in chronic injuries due to repetitive loading. The objective of this research is to conduct animal studies leading to an understanding of the pathophysiology associated with repetitive tool operation.

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Physical and Operational Characteristics

Performance requirements: The performance demanded or likely to be demanded should be fully defined. Examples of items to be considered include: how often the device will be used; likely loading patterns; etc.

- Dimensions/Data
    - Distance from window to handlebar: 1.5cm
    - Mean Max Grip Force: 163 gf
    - Threshold Force: 0.15(163) = 24.45gf
    - Mean Reach Force(from data) = 146.75gf or 1.439N
    - Mean Reach Duration(from data) = 0.1463sec
    - Threshold Reach Duration: 0.05sec
    - Loading Pattern:
        - 4 reaches/min * 30 min/session * 4 session/day
        - 480 reaches/day

Figure 1: As shown in the picture above, the handlebar will be 2.5cm from the slot in the cage wall.

b. **Safety:** Understand any safety aspects, safety standards, and legislation covering the product type. This includes the need for labeling, safety warnings, etc. Consider various safety aspects relating to mechanical, chemical, electrical, thermal, etc.

- The design must be free of pinch points and fire hazards
- If the product is damaged, exposed wires could cause electric shock.

c. **Accuracy and Reliability:** Establish limits for precision (repeatability) and accuracy (how close to the "true" value) and the range over which this is true of the device.

- Resistive force should be able to ramp up to 1.2 N (average pull force of rat) with a resolution of at least 0.1 N (1.2/12 =0.1) giving at least 12 different force settings

d. **Life in Service:** Establish service requirements, including how short, how long, and against what criteria? (i.e. hours, days of operation, distance traveled, no.of revolutions, no. of cycles, etc.)

- The experiment will be run over 6-12 weeks and the device should last for multiple trials

e. **Shelf Life:**

- The apparatus should be stored at approximately 25 degrees Celsius.
- The apparatus should be able to last at least a few years on the shelf while maintaining functionality

f. **Operating Environment:**

- The materials used will be put under stress by the pull of the rat. This is not a very significant amount of force (about 1.5 Newtons), but it will stress materials over a long amount of time. While the experiment is only being run for 6-12 weeks, preferably the device will be able to last for longer than that, in case it is needed for further research. The lab could become humid during the summer months.

g. **Ergonomics:**

- The handle must be small enough to be gripped by a rat. It must be strong enough to not become weak or deformed under the force of the rat pulling on it. The handle needs to be located approximately 8.5 cm above the level of the rat (in order to fit the current model), and it must be located about 1.5 cm from the hole that the rat has to reach through.

h. **Size:**

- The product must be able to fit within the rest of the current model. The box that rats are held in is 31.8 cm tall. The handle is 8.5 cm from the bottom of the box.

i. **Weight:**

- Once our product is installed to the rest of the machine, it will not move. That being said, it needs to be light enough to handled by the average person (50 lbs). Apart from that, there are no weight limitations.

j. **Materials:**

- For the handle, we will need to use a material strong enough to endure pressure over time. No materials are off limits, but the current model uses some type of metal, which would probably work well in our case.

k. **Aesthetics, Appearance, and Finish:**

- Because it is being used to research with rats, the functionality is the only concern for our product. Appearance is not important.

2. **Production Characteristics**

a. **Quantity:** number of units needed

- 1 unit required

b. **Target Product Cost:**

- We are still investigating. Once we begin brainstorming ideas and putting together a bill of materials, we will know more.

3. **Miscellaneous**

a. **Standards and Specifications:**

- FDA approval is not required.

b. **Client:**

- Our client is working with a professor from Temple University. Their main concern is making the new model dynamic, to simulate power tools.

c. **Patient-related concerns:**

- Because the device is being used to test rats, there are no real safety, sanitation, or confidentiality concerns.

d. **Competition:**

- The current model being used is very similar to the model we have been asked to develop. The main difference in the two models is that the current model is static. When the rat pulls on the handle, the force is sensed, and the food is dispensed. Our model will provide a reaction force to the rat when it pulls on the bar