Device To Simulate Biomechanical Exposures Due to Power Tool Torquing

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***Abstract*— Workers in various industries experience exposures to impact due to the use of high-powered torqueing tools. These exposures are associated with an array of Musculoskeletal Disorders (MSDs), particularly in the upper extremity. In order to allow researchers to study these effects as well as to evaluate currently emerging ergonomic interventions, a new research tool is needed. This document describes the design and construction of a novel device capable of simulating biomechanical exposures due to power tool torqueing in a range of 1 to 4,000 Nm. This is accomplished by using a small DC motor to spin a weighted flywheel where, through a clutch mechanism, the torque is transferred to a handle held by the user. The design features easy setup, fast reset times, intuitive user interface, multiple safety features, and is made of durable materials. The entire project weighs less than 40 kg and costs less than 1,000 USD.**

I. Introduction

In many industries around the world, power tools are used in factories to assist workers in applying torque to fasteners. Because of the high amount of force used on these fasteners, the tools used can cause Cumulative Trauma Disorder or CTD in the extremities of the user. This disease is the cause of many injuries each year, resulting in a loss of quality of life for workers, as well as a loss of productivity for companies in addition to liability. Previous research has been conducted on how these tools effect the human body, but in recent years a necessity for new research was created. Biomechanical exoskeletons are used to alleviate the forces on the human body, and research must be done on how long-term use of these exoskeletons may impact the user. This new research will help evaluate if there is any potential risk to the user or help find the benefits of these exoskeletons for even further implementation of biomechanical assist devices. In order to conduct this research, a device to simulate the torque motion of power tools needed to be created. Currently, no product has been widely produced for this purpose.

The objective of our device is to create a user definable torque motion that can be repeatedly applied to a handle and eventually a test subject. Using a small DC motor, a weighted flywheel, a standardized handle, and an array of various sensors and actuators, we were able to replicate the motion of various torque tools.

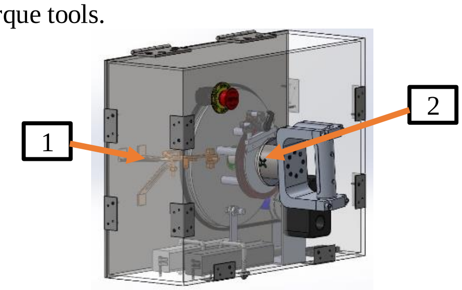

Figure 1. CAD model of the project.

II. Materials and Methods

A. Requirements

The main design constraint encountered was a financial constraint of $1000. Another requirement needed to be met was being safe for lab use. This meant that the design needed to be mountable to T-Slotted 8020 Aluminum, as well as being safe for human testing. To ensure this, multiple emergency stops and other safety features, both software and hardware, were implemented. Because the device is used for human testing, safety is the most important requirement. For performance, the device had to meet the torque requirements of 1 Nm up to 4000 Nm. There were no requirements for the total weight of the project.

B. Protoype Design

This prototype consists of a combination of several custom-made parts as well as ready to order parts. The overall design was fabricated around the idea of a clutch system and simple motor and pulley system. The combination of these two systems as well as a custom braking system was developed to produce the final design.

1. Drive train

The drive train consists of a DC motor that spins a rotating mass which produces a torque once the braking mechanism has been applied. The motor and rotating mass (i.e. flywheel), are connected using a belt.

2. Hardware

The hardware of the system consists of an enclosure, mounting shaft, and handle. The enclosure is made of .00635m steel for the back plate and bottom plate. The rest of the enclosure is made from 0.00635m thick acrylic. The flywheel, brakes, and handle are mounted to a .0254m thick steel shaft that is mounted to the steel back plate. The handle is a certified aluminum handle that is in compliance with ISO-10819 used specifically biomechanical research.

3. Braking System

The first of two braking systems is a spring-loaded caliper that is controlled by a linear actuator. This caliper is used to force together two brake disks that transfer power between the flywheel and handle, similar to a clutch. The second braking system is used for safety precautions. The rotating flywheel has a mechanical brake caliper that is also controlled by a linear actuator. In the event of an emergency, this braking system will be used to make sure unwanted freely spinning mechanisms are coming to a halt.

4. Sensors and Actuators

This system requires an array of sensors and actuators including a Hall Effect RPM sensor, a resistive pressure sensor, linear actuators, voltage relays, resistive strain gauges, and PWM controllers. All of these were controlled using an Arduino Microcontroller (Arduino Mega 2650, Arduino, Sommerville, MA) and LabVIEW software (National Instruments, Austin, TX).

III. RESULTS

In order to maximize the efficiency of power transfer and reduce loss due to friction, the stopping time of our brake system was assumed to be instantaneous (t = .001 seconds). Based off this assumption, we were able to calculate a simple linear relationship of the maximum torque created at different flywheel speeds. The inverse of this relation is used to take the desired torque from the user and convert it to the necessary RPM of the flywheel for each test.

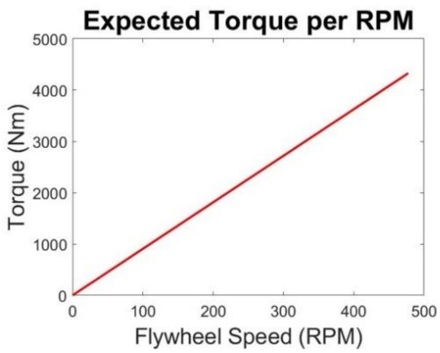

Figure 2. Expected Torque per RPM

In order to test the strength and durability of parts designed by our team, finite element analysis was performed for a maximum torque of 4,000Nm. Each component remained well within a safe range of deformation. The bracket (1) is used to hold the emergency brake caliper that slows the flywheel, while the bearing adapter (2) is the main component that will transfer power from the break disk to the handle.

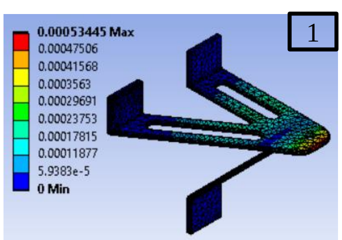

Figure 3. Mounting frame for emergency brakes.

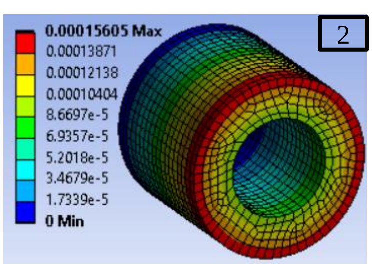

Figure 4. Adapter connecting handle to the braking system.

IV. DISCUSSION

This project has given the researcher the ability to test the torque responses on the human arm according to their own specifications. Many hours of research and development went into creating a device that met the required specifications. Allowing the device to be used by a computer software such as LabVIEW, will result in an easy to use and easily replicable testing interface. Many of the parts in this build were chosen to be easily accessible and replaceable in case of failure or maintenance. Possible improvements to the design include a reduction in overall size through a better optimization of space. A weight reduction may also be necessary as the final project weighs 38.5kg. This will improve mobility of the overall system if it is needed to change positions on the mounting structure in the research lab.

V. CONCLUSION

CTD poses a threat to many workers and they may not even know it. The repeated torqueing motions they endure daily could cause serious harm in the long term. This project has the potential to have a very large effect on the health and safety of factory workers across the world. The research that will be conducted by this device could result in a large reduction in injuries to workers. The design can simulate the motions of power tools used in factories so that the client can study the effects of the motion on human test subjects.

Our design is simple to use as well as simple to construct. The components were selected based on their ease of use and ready availability. It consists of a simple mechanism of a spinning flywheel and a braking system to apply a torque to the handle. This will all be controlled by a computer using LabVIEW software. It will have the ability to test and record various levels of torque applied to the test subject. Through multiple design iterations, the team was able to create a design that is believed to have the best suited the needs of the client of the project. This design will also remain cost effective and under the given budget. It will also be able to remain well within the ethical guidelines for safety and effectiveness.

VI. ACKNOWLEDGMENTS

This project could not have been possible without the help of several people. The team's teaching assistant, Sonali Rawat has worked timelessly with the team's facility advisor, Dr. Ting Xia, to provide feedback on assignments and reports. The project was created for the client, Simon Kudernatsch for the intent of research to be conducted in the BioDynamics lab. Under his specifications, the design was fabricated. Lastly, the university's shop manager, Michael Reynolds has given the team the ability to understand what is feasible to manufacture given the resources available at NIU.