Ironman

T.Thorisson, T.C.Linusson, S.Öberg. L.Birk. B.Chen

Abstract

Isokinetic dynamometers are essential tools for measuring muscle strength, but their high cost and large size limit their use. By creating a more simplified and affordable version, accessibility will increase for clinics, leading to more data for researchers and improved patient rehabilitation.

1.1 Introduction

Isokinetic dynamometers are valuable tools in healthcare and sports medicine because they provide detailed information about dynamic muscle contractions [1]. However, commercial systems are typically large, expensive, and require professional operation, making them difficult to implement in smaller clinics or hospitals [2,3].

Traditional methods like manual and isometric testing cannot accurately capture strength changes during eccentric contractions or across full joint ranges of motion but isokinetic dynamometers address these issues [4]. However by simplifying the design, focusing only on angle and torque measurements, using compact components, a low-cost, motor-driven dynamometer with sensors and 3D modeling support could significantly reduce cost and size, making it more accessible for wider clinical use.

2.1 Design

A small-scale prototype of an isokinetic dynamometer used on the finger was constructed to facilitate the collection of relevant data and validate the practical functionality of the design. The system's motor is operated by a microcontroller (MCU) that uses sensors to control its operation via force and angle from an index finger extension.

2.2 Case Design

The prototype case was designed to house and protect the internal components of the isokinetic dynamometer, while ensuring ergonomic interaction for the user, consisting of three main sections, space for the motor, sensors and MCU. The upper section accommodates the motor and its attached gear as well as a magnetic sensor that’s attached to the motor. Below is additional space for a bottom gear where the load cell is attached to, forming an axis on which the user’s finger applies force to. Then there is more space in the section where the user’s palm will rest that contains most of the MCU and circuitry.

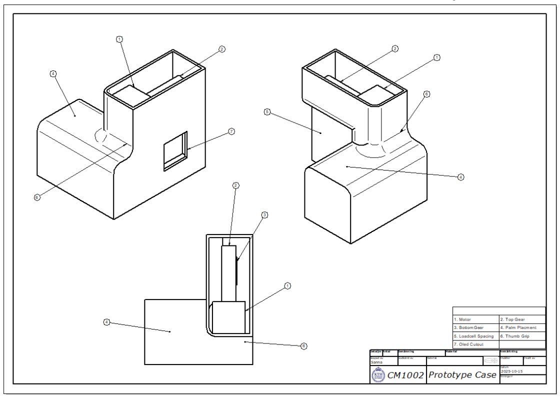

Figure 1 shows a CAD sketch on the intended vision for the final prototype. This sketch can be flipped for right hand usage.

2.3 Gear Design

A worm gear transmission structure can convert the sliding of two helical surfaces into rotation of different surfaces. This design uses this system as the power transmission structure of the dynamometer.

Design decisions were based on threads of ISO TR16×3 to ensure compatibility and 3D printing. To achieve reversible transmission and maintain high efficiency, the worm gear features 24 teeth, resulting in a 24:1 transmission ratio, balancing speed control with a compact design. The module is set at 1.0 mm, the pressure angle at 20°, and the center distance at approximately 20 mm.

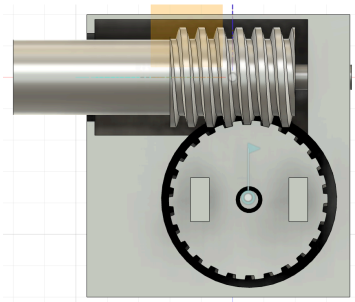

Figure 2 shows the worm drive in transmission structure

2.4 System Design

Electrical schematic are composted by the following components: Arduino UNO R4, HX711 amplifier, AS5600 magnetic encoder, micro SD card socket, 0.96” I2O oled-display, and A4988 motor driver, powering the stepper motor, all connections are shown in figure 3. Because AS5600, micro SD card socket, and HX711 have their own breakoutboards, they are connected externally with pinheaders, as well as the steppermotor. The complete HX711 circuit was added to the schematic for future compatibility. Furthermore, the A4988 gets its + 9 V (Volt) from an external power supply unit, which is only connected to the capacitor, demonstrated in figure 3. The remaining circuitry is only powered by the Arduino’s +5V and ground port, which is in turn powered by an USB-C port attached to the Arduino. Additionally, visual presentation of a potential PCB is illustrated in figure 4.

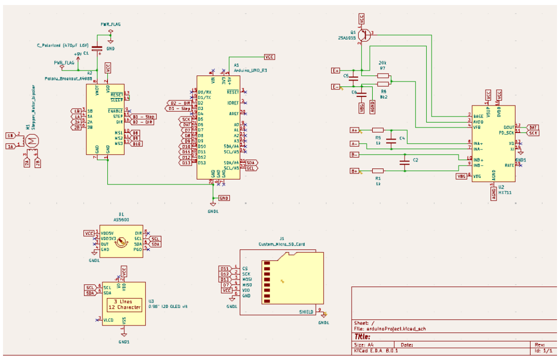

Figure 3 shows a KiCad schematic of the electrical design.

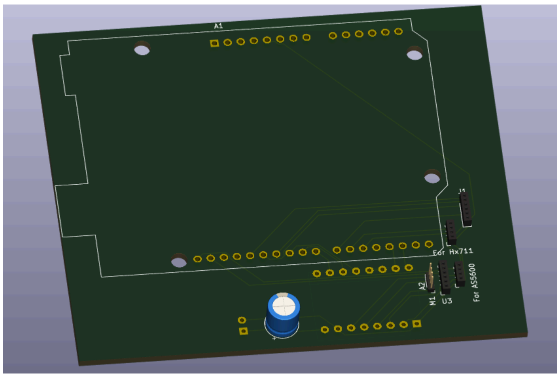

Figure 4 shows a visual representation of the potential PCB.

2.5 Software Design

The software combines all the working components as well as documenting all the data in real time. Furthermore the software saves all the data, showing applied force at a certain angle.

3.1 Results

The results show that the first prototype can measure the applied force as well as the corresponding angle which in turn was intended as shown in figure 5.

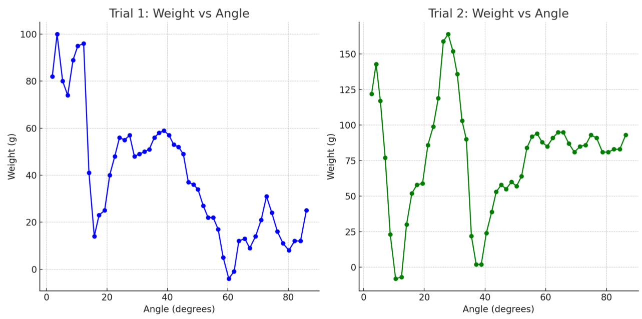

Figure 5 shows a graph of the applied force on depending on the angle of the sensor

4.1 Conclusion

In conclusion, isokinetic dynamometers are essential tools for measuring muscle strength, but their high cost and large size limit their use. The objective with this project was creating cheaper and simplified versions to implement in healthcare. The prototype was constructed to validate the practical functionality of the design by making a small-scale prototype for the finger. The system is operated by a microcontroller that uses sensors to control its operation via force and angle alongside a motor. Although, the prototype demonstrates that small, economical dynamometers are feasible and have potential for use in rehabilitation applications in the future. Whereas potential future work should implement a more structured and detailed planning approach, implementing a better gearbox and motor for increased torque.

5.1 Future Work

For future projects, the group would highly recommend adopting a more structured and detailed planning approach earlier in the process. The initial phase suffered from a slightly unclear project vision and a rush towards implementation and meeting deadlines. This resolved some stress at the end and making some emergency solutions on the prototype. Future ideas for improvements could be, implementing a planetary gear box for increased torque and helical gear to transport the movement to the gearbox. Together with a DC motor in order to have precise control and more force available. What's the next step? Either continue adjusting and developing the current prototype or moving forward by making the next prototype. A bigger variant for the leg area, that will be more simplified, affordable, and has an increased accessibility for e.g., clinics. This is because the prototype demonstrates that the idea works and can be produced with further time.

6.1 References

[1] "Isokinetic dynamometry: implications for muscle testing and rehabilitation," PubMed, 1986. https://pubmed.ncbi.nlm.nih.gov/3525192/

[2] M. Mendoza M., R. Miller RG, California Pacific Medical Center, and Elsevier Inc., "Muscle Strength, Assessment of," Encyclopedia of the Neurological Sciences (Second Edition), 2014.

[3] R. Gülch, "Force-Velocity relations in human skeletal muscle," International Journal of Sports Medicine, vol. 15, no. S 1, pp. S2–S10, Jan. 1994.

[4] A. Ivarsson and A. Cronström, "Agreement between isokinetic dynamometer and hand-held isometric dynamometer as measures to detect lower limb asymmetry in muscle torque after anterior cruciate ligament reconstruction," International Journal of Sports Physical Therapy, vol. 17, no. 7, Nov. 2022.

7.1 Appendix

Github link:
https://github.com/Alfonzo47/Main-Project