Custom Automated Tensile and Compression Tester

Research Toward Carbon Fiber, 3D Printed, High Performance Custom Footwear

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Abstract

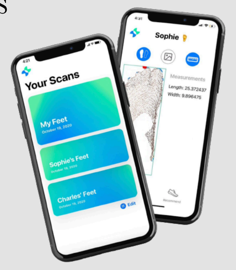
Continuous Carbon Fiber (CCF) is a recent method of 3D printing with carbon fiber composites. Its introduction to the personalized footwear industry yields a wide spectrum of benefits: enhanced flexibility, high elastic deformation and heat resistance, lightweight, faster shape recovery, corrosion resistance, and increased compressive and tensile strength. However, given the extensive resources and funds required for using CCF, one of the major challenges is finding a balance between the number of passes of laid carbon fiber and shoe integrity. The custom-built Tensile Tester poses a reliable solution to standardizing the integrity of custom 3D printed footwear exoskeleton. An onboard raspberry pi, 100kg load cell, and 1320lb linear actuator function as one system to standardize the required passes of laid carbon fiber for a specific compressive strength, ensuring a balance between footwear integrity, and manageable manufacturing costs.

Introduction

"Sixty percent of people at any given time are walking around in the wrong size shoe. Half a million people complain about purchasing the wrong shoe size per year– just in North America" (Marchese, 2019)

Quick Review

- Over the past decade, the personalized footwear industry has welcomed a future where digital technologies transformed the customer journey (How 3D Printed, 2020).
- 3D shoes launches first custom platform and 3D printed shoe in 2015
- Now many companies involved in the footwear personalization industry: Nike, 3D Shoes, Neasty, Wiivv, Feetz, Ecco, Dodge Ski Boots
- Three Step Process
  1. Custom Scan
  2. 3D Modeling
  3. 3D Printing

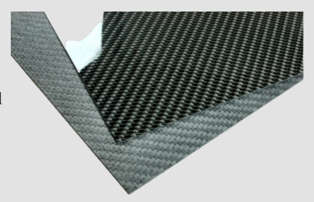


Lomas, 2020

Continuous Carbon Fiber (CCF)

- What is it?
  - Continuous Carbon Fiber (CCF) is a recent method of 3D printing with carbon fiber composites, yielding the following benefits:
    - Enhanced flexibility, high elastic deformation and heat resistance, lightweight, faster shape recovery, corrosion resistance, and increased compressive and tensile strength

Solid Carbon, n.d



Carbon Fibers, n.d

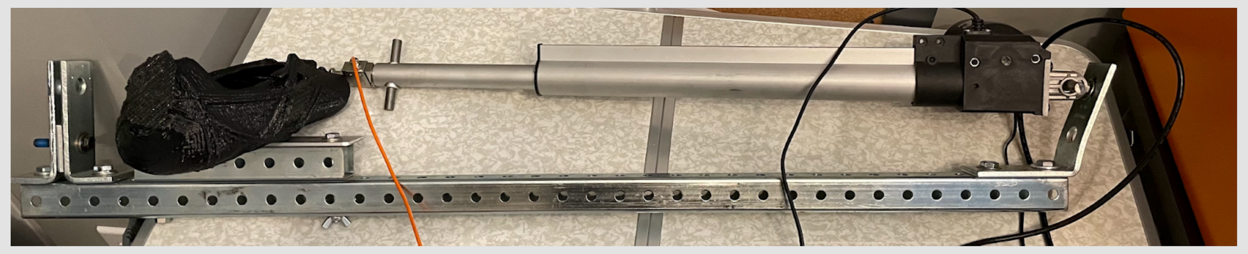
Issue

- Given the extensive resources and funds required for using CCF, one of the major challenges is finding a balance between the number of passes of laid carbon fiber and shoe integrity.

Solution

- Goal: designing, constructing, and programming a reliable solution to measuring and standardizing the integrity of custom 3D printed footwear exoskeleton.
- Using a raspberry pi to intake analog readings from a load cell to automate the extension and retraction of a linear actuator, the custom-built machine brings further promise to improve and accelerate the high performance personalized footwear industry.
- What sets my tester apart from the existing industry machines?
  - On board microprocessor raspberry pi.

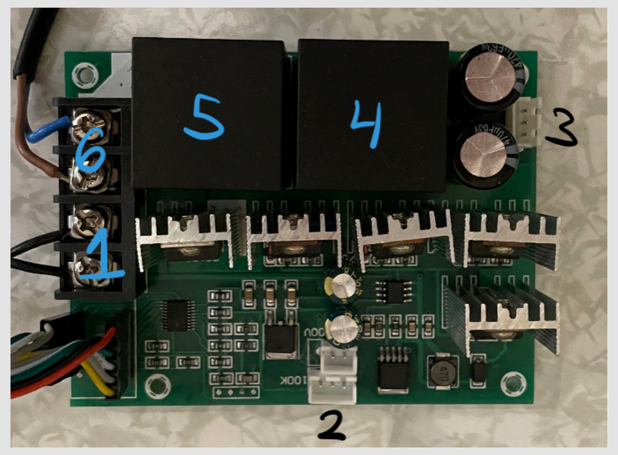
Hardware Methods



- Connected to the base shaft is a mounting platform for the tested object
- 3D printed shoe is screwed in for minimal movement during testing.
- On the right end of the base shaft sits an "L" shaped metal piece to attach the linear actuator
- The tip of the linear actuator shaft houses the load cell. This load cell sends a reading of the applied force on the 3D printed shoe to the raspberry pi.

Electrical Methods

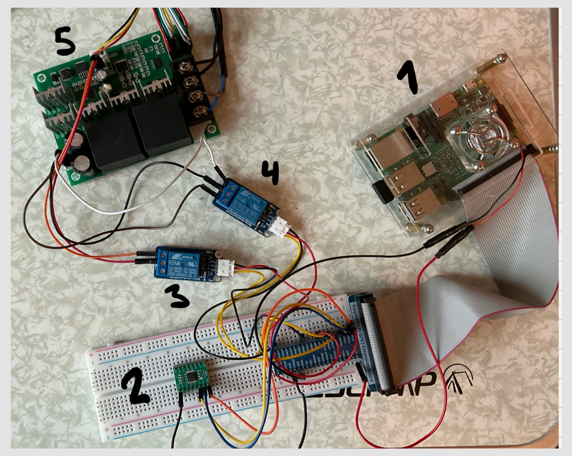
Main Module



Numbers 1 through 6 illustrate the path of current through the module in order:

1. Power was connected via an outlet into the outlet on the far left
2. Speed control of the linear actuator via a SunFounder Relay Module
3. Similar to the manipulation of port 2, a "SunFounder" relay was used for port three to control the direction of the linear actuator.
4. In-house relay number one used to transmit the current from the circuit to port 6.
5. In-house relays number two used to transmit the current from the circuit to port 6.
6. Current used to power the linear actuator and send signals of which direction to move.

Raspberry Pi, Breadboard, Relays, GPIO Extension Board



Numbers 1 through 5 correspond to current path to "main module":

1. Raspberry Pi 4 8 GB Ram (with GPIO extension)
2. Breadboard
3. "SunFounder" (connected to port 3)
4. "SunFounder" (connected to port 2)
5. Main Module

Software Methods

- **Load cell calibration:** reading voltages of known masses and changing the pi analog input value accordingly. Values were confirmed via a third party datasheet
- **Main methods:**
  1. Intake()
  2. Out()
  3. On ()
  4. Off()
- **Pseudo Code:**
  1. "Out" method was ran until desired force from the load cell was met
  2. Tensile tester turn off to maintain x-position momentarily
  3. Run Intake() until no more pressure is applied to the 3D printed shoe.

Results & Discussion

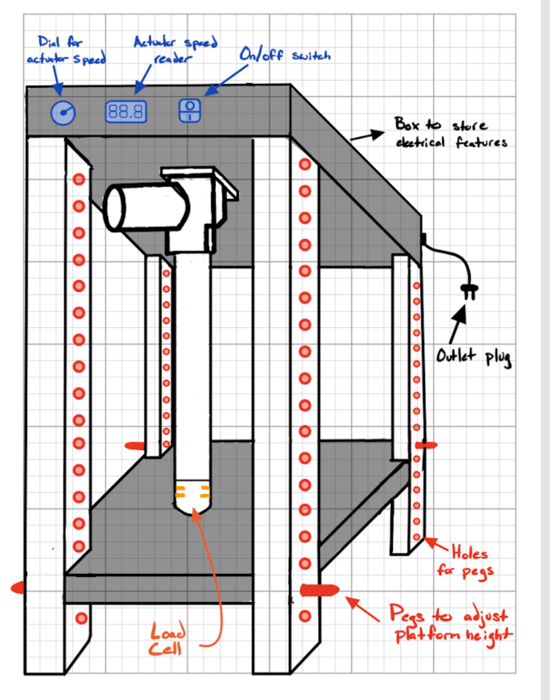
The Automated Tensile Tester was...

1. Ultimately successful in ***measuring*** the compressive for applied to the shoe
2. Able to function (retract or extend) accordingly in ***response*** to the measured forced
3. Capable of ***standardizing*** force applied to the 3D printed object

Future Enhancements:

Enclosure:

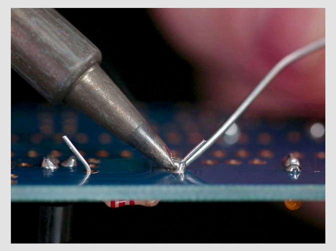
- An enclosure for the tensile tester is aimed to increase user safety during testing trials as well as reduce variation in testing (essential in standardizing applied force to the tested object)
- Enclosure Components
  1. 1/4 in steel platform
  2. 4 UNISTRUT steel rectangular columns
  3. 2 steel rods (or pegs)
  4. Linear actuator
  5. Plastic box to store electronics
  6. Speed dial
  7. Actuator speed reader
  8. On/Off Switch
  9. Outlet plug



Wire Management:

- Connection cables from the GPIO breadboard to the main module require wire management
- The hundreds of connections can easily be unplugged or partially removed from their socket as well as confused with one another.
- Solution:
  1. Wires will be soldered to the GPIO board
  2. Connections will be color-coordinated
  3. Heat shrink will be used to reduce clutter

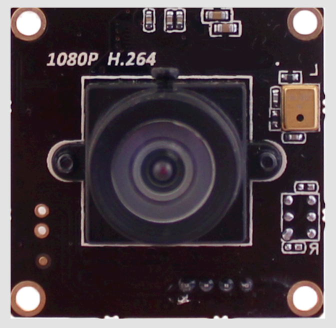
LTF100 GENERAL, n.d.



Cunningham, n.d.

High Resolution Camera:

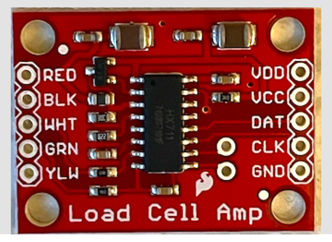
- Camera aimed at the tested object can quantify the amount of shoe deformation
- High resolution camera (specifications still to come) can be programmed using pre-existing libraries that count the change in pixels and return a percentage of deformation.
- Visualizations can be generated that display the deformation of an object as a function of the applied compressive force
- Camera will be housed roughly forty-five degrees above the horizontal, and will be fastened onto one of the enclosure UNISTRUT columns



Low-Light HD USB Camera, n.d.

Design Considerations

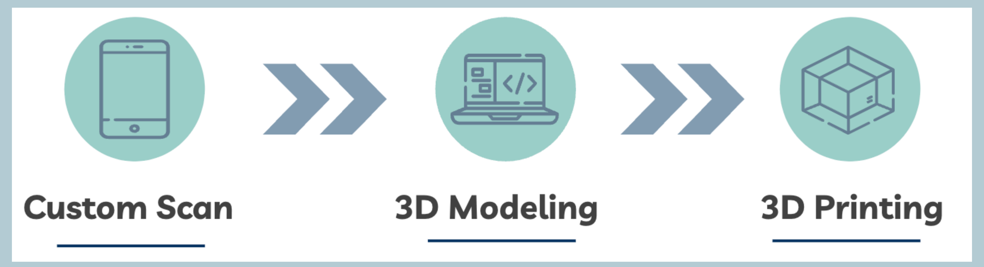
- The main roadblock during the development of the tensile tester was reading the input from the load cell.
- When the ADC first tried to directly read the voltages from the load cell without an amplifier, the voltmeter was unable to pick up a voltage (it read 0.00).
- It was concluded a "load cell amplifier" is a necessary median between the load cell and the analog input on the ADC



Conclusion

Area of Study

- Shattering a prior tradeoff between precision and accessibility, high computing smartphones have demonstrated the ability to enable widespread footwear personalization (Farhan et al., 2021).
- This evolution has enabled the capability for this three stage process:



Issue Review

- The issue that my research addresses is in the "3D Printing" stage
- Companies printing with CCF must strike a balance between passes of laid carbon fiber and cumulative expenses in order to continue pushing the boundless potential of high performance custom carbon fiber footwear (Shen et al., 2019).

My Research

- The device enables users to standardize the required passes of laid carbon fiber for a specific compressive strength, ensuring a balance between footwear integrity, and manageable manufacturing costs.
  - With the common goal to further research in custom 3D printed footwear, the tensile and compression tester will yield further confidence in the complex printing of carbon fiber 3D printed custom footwear.

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