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Rapid Orthotics for CURE Kenya - Mechanical Design and Official Testing of 3D Printed Sockets

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Our Mission

ROCK works with CURE International Hospital, a non-profit orthopedic workshop in Kjabe, Kenya, to implement a 3D printing system for manufacturing custom prosthetics and orthotics.

The system will:

- Assist technicians with high volume of patients seeking care for prosthetic leg sockets.
- Reduce the production time and cost for transtibial sockets being manufactured.
- Give patients a way to integrate into society and reduce stigma from their communities.

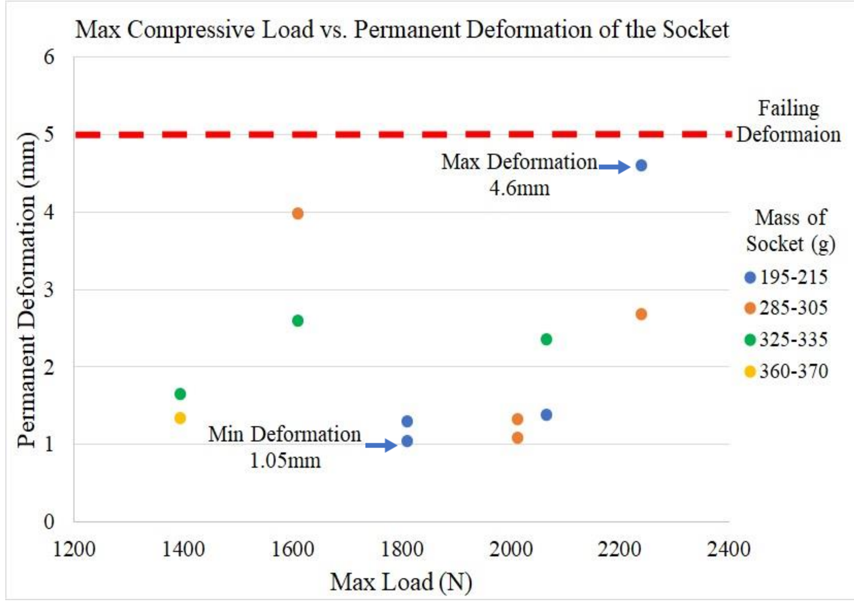
Manufacturing of Metal Shin Jig

To follow the geometrical offsets specified in the ISO 10328 Standard, hardware was constructed that would interface with the MTS machine at Messiah University. Initially, the jigs were designed out of wood due to its strength under compression. However, the long wood jig and the short wood jig both failed under compressive force along the grains in Spring of 2021. After conducting research and consulting with Dr. Van Dyke, the new jig was designed out of steel with an epoxy mold that sits in the base of the socket to prevent shifting during testing and to withstand the compressive forces of the tests specified in the ISO 10328 Standard. The steel rod was designed such that it is compatible for test Type I and II with the added extension rod.

Official Testing

To determine the safety of the sockets, the ISO 10328 Standard specifies the force magnitude and offsets for each test type and condition. The various tests replicate the forces experienced during walking. For each test, the standard specifies the angle of the applied force using certain offset distances within a unique coordinate system. After several initial designs were scrapped due to their inability to accommodate the complex geometry that was needed, the team developed a novel rig, called the MTS Testing Adaptors and developed a testing procedure for the Ultimate Strength and Static Proof Tests. The standard requires a minimum of twelve test be completed, two trials for each of the following: P3 TI&II, P4 TI&II, P5 TI&II.

Testing configuration in MTS machine



Final testing graph displaying the twelve official tests

Twelve Completed Official Tests

Passing Criteria specified by the Standard:

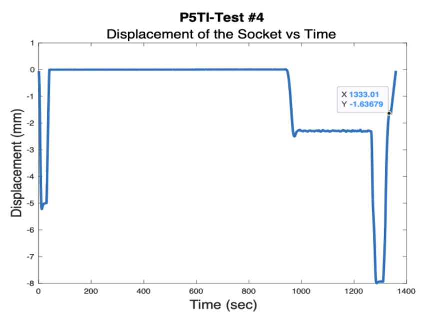
- The Standard dictates the max load for the specified condition
- The final deformation must not exceed 5 mm of deformation

Completion of the Twelve Tests:

- The twelve samples passed the tests required by the standard
- The masses varied between the different tests

Data Analysis

- The MTS machine exports raw data collected during testing
- MATLAB code written to analyze exported CSV file
- Force vs Displacement and Force vs Time Graph are produced



Graph produced by MATLAB

Our Goal

The team has established a system for 3D printing transtibial sockets for below-the-knee amputees. Prior to implementing the system in the orthopedic workshop, the team intends to validate the safety of the sockets using the offsets and conditions specified in the ISO 10328 Standard. The team has strictly followed the offsets and conditions to develop a rigorous testing procedure for the Ultimate Strength and Static Proof Tests. The team intends on finalizing the safety testing of the sockets by designing a procedure for Cyclic testing.

3D Printed Transtibial Socket

3D Printing

Optimization of Printing Settings

Previous Problems with Prints:

- Poor surface finish
- Inconsistent mass between sockets
- Shifted layers in newer prints

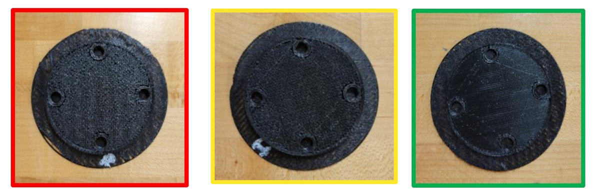
Settings Changed:

- Infill pattern
- Z-offset (for PLA to adhere)
- Printing speed
- Outline shell and solid layers

Poor quality socket with shifted layers | Poor surface finish | Best quality socket

Infill Optimization

When testing different settings on the 3D printer, several of the sockets experienced delamination making them flexible. After investigation, the delamination issue was found to be caused by inconsistent infill, which lead to mass inconsistency even though the socket was being printed at



100% infill. The team printed a few trials, varying the infill patterns: rectilinear (red),triangle (green), wiggle, and honeycomb (yellow). The triangle infill proved to be the best infill pattern due to its consistent texture and mass.

Conclusion

The team has successfully completed the required twelve official tests specified by the ISO 10328 Standard. Prior to testing, the wooden jigs were replaced by a manufactured steel jig with an epoxy mold and an extension rod to be compatible for test Type I and II. The optimized printing settings were established to maintain the quality of 3D printed sockets. The focus of next year will be to complete the cyclic testing specified in the standard. Further modifications may be made to both the socket and the method of printing to most efficiently implement a safe and functional 3D printing system in the orthopedic workshop at CURE Kenya.

Our System

The system is comprised of an iPad with a photo sensor attachment used by the orthopedic technicians to scan the residual limb, converting the digital image to a file that can be customized in Omega Software. The file is transferred to Meshmixer Software where the pyramid adaptor is attached, and the file is converted to be printed by the Delta Wasp.

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