DEAD BLOW HAMMER IN ORTHOPEDICS

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ABSTRACT

Total joint replacements surgeries can be physically difficult on both the patient and the surgeon because of the large amounts of force exerted. Our client, Dr. John Wollaeger, came to the group because this causes wear and tear on the surgeon's shoulder and elbow joints Also, the amount of force needed to be generated by the surgeon limits the field of surgeons that are physically capable to perform such surgeries. To solve this problem, our group has designed an orthopedic mallet that limits recoil and limits the force needed to be generated by the surgeon by use of a dead-blow style hammer, which are typically used in construction settings. A prototype has been created and tested to confirm the ideal force curve that is expected when in use compared to current orthopedic mallets. The next step in this project is to manufacture a heavier duty prototype to calculate max force generation, and eventually a prototype manufactured with medical grade stainless steel.

PROBLEM STATEMENT

Design Motivation:

- Current orthopedic mallets have significant recoil upon striking a chisel during surgery
- Large amounts of force must be generated by the surgeon swinging the mallet

Objective:

Create a mallet to be used in orthopedic surgeries that lowers the force exertion needed by the surgeon and limits the recoil caused from striking the chisel during surgeries.

BACKGROUND

Figure 1: Dead-blow hammer for construction and manufacturing [1]

Figure 2: Coronal (left) and sagittal (right) views of a knee replacement [2]

Dead Blow Hammers

- Primarily used in the construction industry [1]
  - Minimize damage to the struck surface
  - Allow one to help control their striking force
  - Produce minimal recoil comparatively
- Steel beads within these hammers contribute to much of their characteristics

Orthopedic Surgery Application

- This device has not been utilized effectively in the medical industry yet
  - Several patents currently exist
  - Our device would exist as a Class 2 Medical Device [5].
- Orthopedic surgeries currently use a "surgical hammer" or "orthopedic mallet" for large joint replacements (i.e. knee, hip, etc.) [2,3]
- Surgeons often have to use excessive manual force to perform total joint replacement [2,4].

DESIGN CRITERIA

- Able to exert 40 kN onto the body which it is striking
- Limit recoil upon impact when compared to currently used mallet
- Lightweight enough to limit physical stress for surgeon (0.45-1.35 kg)
- Able to be sterilized with current autoclave protocol
- Material must not interfere with patient's biological systems

FINAL DESIGN

Components:

- Mallet Outer Shell
  - Medical grade stainless steel
- Caps
  - Threads to screw onto head
  - 304 stainless steel
- Handle
  - Knurled for ergonomics
  - 304 stainless steel
- Metal beads
  - Steel (lower grade than stainless)
  - Amount of beads is variable

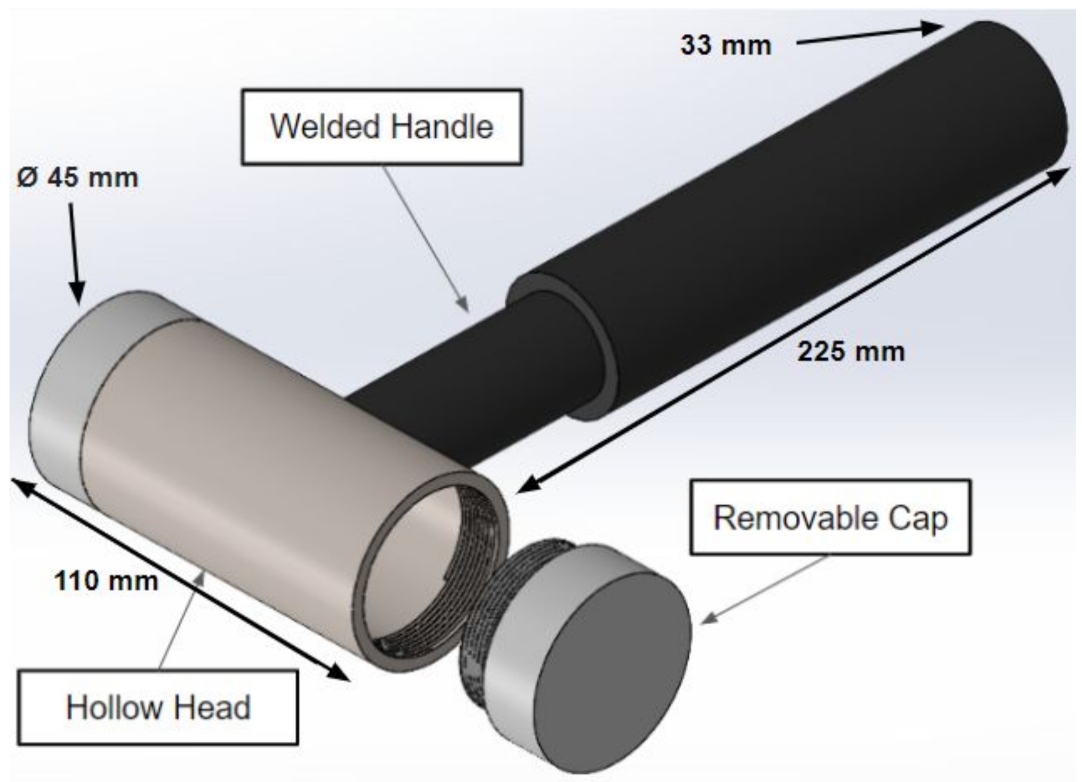

Figure 3: Solidworks rendering of Replaceable Cap Design

TESTING AND RESULTS

- **Testing Procedure:** A force plate was struck by our stainless steel prototype. One test with beads (Dead Blow) one test without (Control) to determine the force-time characteristics. Each one was struck 5 consecutive times, which was then repeated 4 times for a total of 20 strikes each.

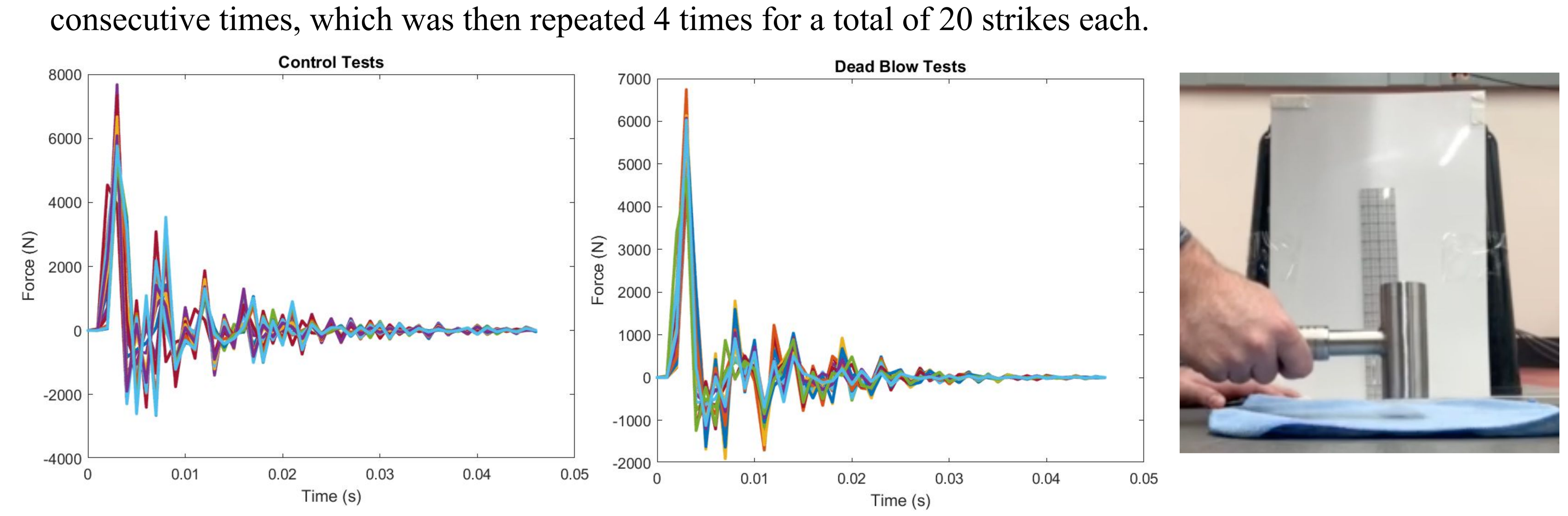

Figure 4: Force-time plots for the control mallet (left) and dead blow mallet (middle) and a force plate strike with dead blow mallet (right).

- **Results:**
  - *Normalization:* In order to account for differences in human operation, each data point was divided by the max force before analysis.
  - *Dampening:* Dampening was found by comparing the normalized force of the control and dead blow tests at 1 ms intervals (for 6 ms) from the max strike force for each test.

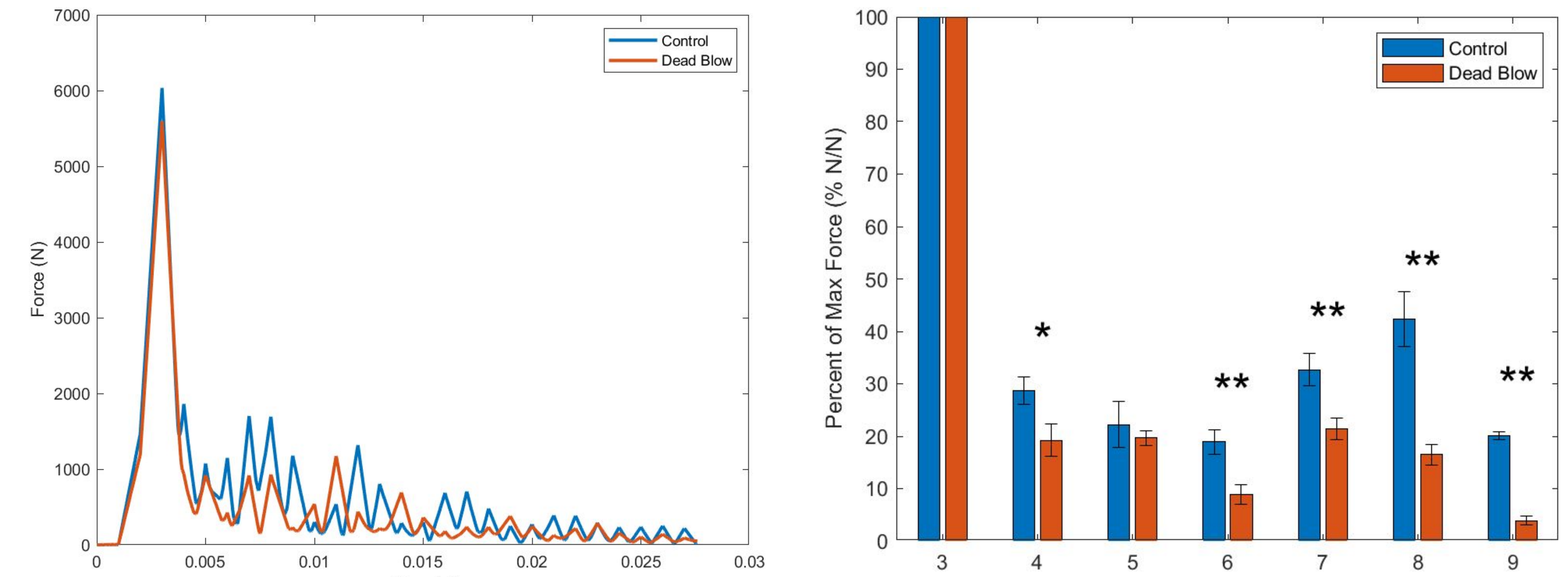

*Figure 5: Force-time plot of averages for all 15 tests of each mallet. The left plot is for the average force values. The right plot shows the average normalized forces for 6 residual peaks. ($p<0.05$ = *; $p<0.01$ = **)*

DISCUSSION

1. **Force Plate Sampling:** A faster sampling rate (100-200 kHz) would allow for impulse characterization of the strikes. Also, the 1 kHz rate may have limited accuracy.
2. **Dampening:** Dampening was characterized by the measured forces after the strike. The Dead Blow tests saw significantly lower residual forces, which was used to characterize dampening.
3. **Normalization:** In order to account for differences in each swing, the data was normalized to the max force for each strike.
4. **Possible Errors:** Other sources of error include: inconsistency with the swing, inherent error from sensors, and striking at a slight angle to the plate.

FUTURE WORK

Improvements:

- Remove weight from the handle
- Expand upon the viability of a silicon or similar handle
- Find optimal amount of beads for mallet
- Implement a flexible inner casing for the beads

Testing:

- Test with a faster sampling rate to determine impulse characteristics of initial strike.
- Add lever arm to limit human error in force plate striking.

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