# BME Design-Fall 2021 - WILLIAM BROWN
# Complete Notebook

PDF Version generated by

WILLIAM BROWN

on

Dec 15, 2021 @12:48 PM CST

## Table of Contents

# Team contact Information

ISAAC KRAUSE - Dec 15, 2021, 12:11 PM CST

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# Project description

WILLIAM BROWN - Dec 02, 2021, 11:22 AM CST

**Course Number:** BME 400

**Project Name:** Dead Blow Hammer in Orthopedics

**Short Name:** Dead Blow

**Project description/problem statement:**

Mallets are often used in orthopedics to insert metallic items into the medullary canal of bones. Examples of this are total joint replacements and intramedullary rods for fracture care. A dead blow hammer is a device that limits blowback and concentrates force upon striking a material. The goal is to develop a hammer that can be sterilized while also providing advantageous results when compared to orthopedic hammers currently in use.

**About the client:**

The teams' client, Dr. Wollaeger, is an orthopedic surgeon here in Wisconsin. He came to the BME department with the idea of improving the efficiency of orthopedic mallets in such a way that would limit chronic injury to surgeons.

# Client Meeting One (9/13)

CONNOR LINK - Sep 13, 2021, 2:51 PM CDT

**Title: Initial Client Meeting**

**Date:** 9/13/2021

**Content by:** Connor Link

**Present:** Connor Link, William Brown, Sam Ferris, Isaac Krause, Dr. Wollaeger (Client)

**Goals:** Establish common goals and answer initial questions

**Content:**

1. Basic Idea of Orthopedic Hammers
    1. A lot of orthopedic require large implants -- generally use a press fit
    2. Basically hammer these large materials in -- look at videos of total knee or total hip replacements for examples
    3. This is a very hard hit that has to be precise
    4. Hitting metal on metal with a sharp blow
    5. The dead-blow construction mallet helps to dissipate the energy which leads to a more precise blow and with less recoil
2. Guiding Questions
    1. Questions:
        1. Is the hammer gentler while still providing a proper amount of force?
        2. Is there less rebound?
            1. Essentially is it better than a normal hammer
        3. If there is a way to make this can we ensure the shot is not going to go into the patient?
3. Other Notes
    1. We will keep in contact with Dr. Wollaeger throughout the course of the semester.
    2. Dr. Wollaeger could maybe get us a sawbone (fake bone) to test the design
    3. What material would he like it to be made of?
        1. Good with using a polymer with a secondary cap if broken -- does not have to be metal
    4. The weight is usually about a couple of pounds -- if it gets too heavy it is too tiring, if it is too light it may not be effective
        1. Look into designs of currently used orthopedic hammers
    5. Generally the hammers that are used now are just a solid piece of metal
    6. Sterilization process for hammers
        1. Look into this information (we will do that)
    7. Progress Checks:

1. Tuesday afternoon is generally pretty open for him
2. We will reconvene on the 28th of September
3. We will send weekly updates of the progress for the week

**Hard but subtle.**

**Conclusions/action items:**

- We will have another progress meeting over Zoom with Dr. Wollaeger on Sept 28th. Time is TBD.
- Begin background research and come up with initial design ideas
- Begin working on the PDS

# Client Meeting Two (9/28)

WILLIAM BROWN - Oct 20, 2021, 8:20 AM CDT

**Title: Client Meeting Two (PDS)**

**Date:** 9/28/2021

**Content by:** William Brown

**Present:** Connor Link, William Brown, Sam Ferris, Isaac Krause, Dr. Wollaeger (Client)

**Goals:** Update Dr. Wollaeger and confirm any questions.

**Content:**

This meeting was an update on where we had gone for the PDS. Dr. Wollaeger mentioned no concerns with the PDS that we sent him earlier in the week. The team updated Dr. Wollaeger on the upcoming steps in the design process and talked to him about our plans to get our hands on a testing protocol so we could begin fundamental testing with a commonly used orthopedic mallet. This will be the research for the foreseeable furture.

**Conclusions/action items:**

- We will meet again after preliminary presentations and deliverables

# Client Meeting Three (11/16)

WILLIAM BROWN - Dec 15, 2021, 9:45 AM CST

**Title: Client Meeting Three (Fabrication)**

**Date:** 9/28/2021

**Content by:** William Brown

**Present:** Connor Link, William Brown, Sam Ferris, Isaac Krause, Dr. Wollaeger (Client)

**Goals:** Update Dr. Wollaeger about the design process and explore fabrication ideas

**Content:**

The team presented Dr.Wollaeger with our proposed design process going forward. This would be 3D printing a prototype out of PLA material before making one out of metal. This would save money as well as allow the team to get some great preliminary data. Dr.Wollaeger was satisfied with this idea as well as satisfied with other updates about the project.

**Conclusions/action items:**

- The idea from this meeting is that having a lower fidelity prototype if perfectly fine to begin testing.

# 2021/09/10 - Introduction Advisor Meeting

WILLIAM BROWN - Sep 13, 2021, 11:16 AM CDT

**Title: Intro Advisor Meeting**

**Date:** 9/10/2021

**Content by:** William Brown

**Present:** Dead Blow Hammer team, and others under the advisement of Dr. Tracy Puccinelli.

**Goals:** To set up meeting times with teams and understand the work that will need to be completed this semester.

**Content:**

- Team meeting for Dead Blow assigned to 1:00 PM Fridays with Dr. Puccinelli.
- Understood that constructive criticism is supposed to be just that, constructive. Dr. Puccinelli described past experiments with students breaking down their teammates and not building them up. (she noted this should be changed this semester).
- Assigned group roles within the team directly after meetings conclusion. (William: Team Leader, Sam: BSAC+BPEG, Connor: Communicator, Isaac: BWIG,)

**Conclusions/action items:**

This entry keeps the notebook up to date with the beginning of class.

# 2021/09/17 - Team Meeting

WILLIAM BROWN - Dec 15, 2021, 10:06 AM CST

**Title: Team Meeting One**

**Date:** 9/17/2021

**Content by:** William Brown

**Present:** Connor Link, William Brown, Sam Ferris, Isaac Krause, Genevieve Boudreau

**Goals:** Introduce Genevieve to our project and update Her on where we stood.

**Content:**

This meeting was an introduction to where our team would like to take this project. It was nice to learn about the first-year medical student here at the University of Wisconsin.

**Conclusions/action items:**

- We will meet with her again likely after preliminary presentations and deliverables

# 2021/09/20 - Team Meeting

WILLIAM BROWN - Dec 15, 2021, 10:24 AM CST

**Title: Team Meeting Two (PDS)**

**Date:** 9/20/2021

**Content by:** William Brown

**Present:** Connor Link, William Brown, Sam Ferris, Isaac Krause

**Goals:** Discuss Aspects of the PDS to be completed and worked through.

**Content:**

The team met at ECB and well as on zoom to discuss the parts of the PDS that each of our teammates could work through.

**Conclusions/action items:**

- Goal is to continue to have meetings like this for design updates.

# 2021/09/25 - Team Meeting

WILLIAM BROWN - Dec 15, 2021, 10:32 AM CST

**Title: Team Meeting Three Design Matrix**

**Date:** 9/25/2021

**Content by:** William Brown

**Present:** Connor Link, William Brown, Sam Ferris, Isaac Krause

**Goals:** Discuss Aspects of The Design Matrix to complete.

**Content:**

This meeting comprised of the team talking about what the basis of the design matrix should be. The team delegated parts of the matrix to each other and worked on completing it before the Friday deadline. Below are the ranks of each category.

**Durability (25)**
**Effectiveness (20)**
**Safety (15)**
**Ergonomics (10)**
**Cost (10)**
**Ability to be Sterilized (10)**
**Ease of Fabrication (5)**

**Conclusions/action items:**

- Goal is to complete the rationale for the design criteria and turn in the design matrix.

WILLIAM BROWN - Dec 15, 2021, 10:21 AM CST

The majority of our communication for the project was done in our group chat. This is where we would hold some team meetings aswell as talk about parts that need to be completed.

# 2021/10/20 - Team Meeting

WILLIAM BROWN - Dec 15, 2021, 10:34 AM CST

**Title: Team Meeting Four Show and Tell Prep**

**Date:** 10/20/2021

**Content by:** William Brown

**Present:** Connor Link, William Brown, Sam Ferris, Isaac Krause

**Goals:** Discuss the idea of our show and tell project.

**Content:**

This meeting was over zoom and in our group chat. We discussed what problem we wanted to look to our classmates for help with. We settled on asking them about ways we could test the force of the hammer without using a force washer or damaging a force plate. We also talked about what we could potentially say in our show and tell meeting.

**Conclusions/action items:**

- I think the idea of asking about ways to test the force of the hammer was the best route our team could have went.

# 2021/12/3 - Team Meeting

WILLIAM BROWN - Dec 15, 2021, 10:34 AM CST

**Title: Team Meeting 5 testing Prep**

**Date:** 12/3/2021

**Content by:** William Brown

**Present:** Connor Link, William Brown, Sam Ferris, Isaac Krause

**Goals:** To complete the testing procedure as a group

**Content:**

The team met over zoom to fill out a testing procedure which can be found in the testing folder of the notebook. The idea was to make a testing procedure that would provide the team with accurate results as well as a procedure that would not damage the force plate.

**Conclusions/action items:**

- The best part of this meeting was that we had done other work on testing procedures in the past so the group made this a quick meeting.

# 2021/12/5 - Team Meeting

WILLIAM BROWN - Dec 15, 2021, 10:37 AM CST

**Title: Team Meeting 6 Final Poster**

**Date:** 12/5/2021

**Content by:** William Brown

**Present:** Connor Link, William Brown, Sam Ferris

**Goals:** The members of the group that completed testing wanted to finish the final poster and prepare for presentations.

**Content:**

After testing the prototypes, the team talked about things that would need to be added to the poster and to the presentation in order to complete the deliverables before Friday's deadline.

**Conclusions/action items:**

- This was the last team meeting that the group had for the semester. We would continue communication via groupchat.

# 2021/09/21- Preliminary design brainstorming

WILLIAM BROWN - Sep 21, 2021, 5:09 PM CDT

**Title: Preliminary Design Brainstorming**

**Date:** 9/21/2021

**Content by:** Sam Ferris, William Brown

**Present:** Isaac, William, Connor, Sam

**Goals:** Brainstorm ideas for preliminary design and discuss how to create the 1st PDS draft

**Content:**

- Connor introduced his preliminary ideas.
    - brainstorm designs
- PDS discussion:
    - which sections each student should take.
    - weights of each category
    - talked through client requirements
- Completed the Function and Client Requirments for the PDS
- Talked about the upcoming client meeting next Tuesday.
    - The team wants to get materials and see other tools used by orthopedic surgeons. (will ask the client about this).
- Prepare an update meeting with Medical Student teammate
- Outsource fabrication:
- Ask Dr.TJP more Friday
- Thought about design expensess

**Conclusions/action items:**

Finish the PDS and continue working on finishing preliminary designs.

# 2021/10/24 - Redesigned Handle

WILLIAM BROWN - Dec 15, 2021, 9:01 AM CST

**Title:** Redesigned Handle as Designed in Solidworks

**Date:** 10/24/2021

**Content by:** Connor Link

**Goals:** Make edits to the handle for the mallet based on the ergonomics research

**Content:**

The mallet was redesigned to account for maximal ergonomic comfort for the surgeon. The inner chamber was also increased in size in order to provide more volume in which the beads can be placed.

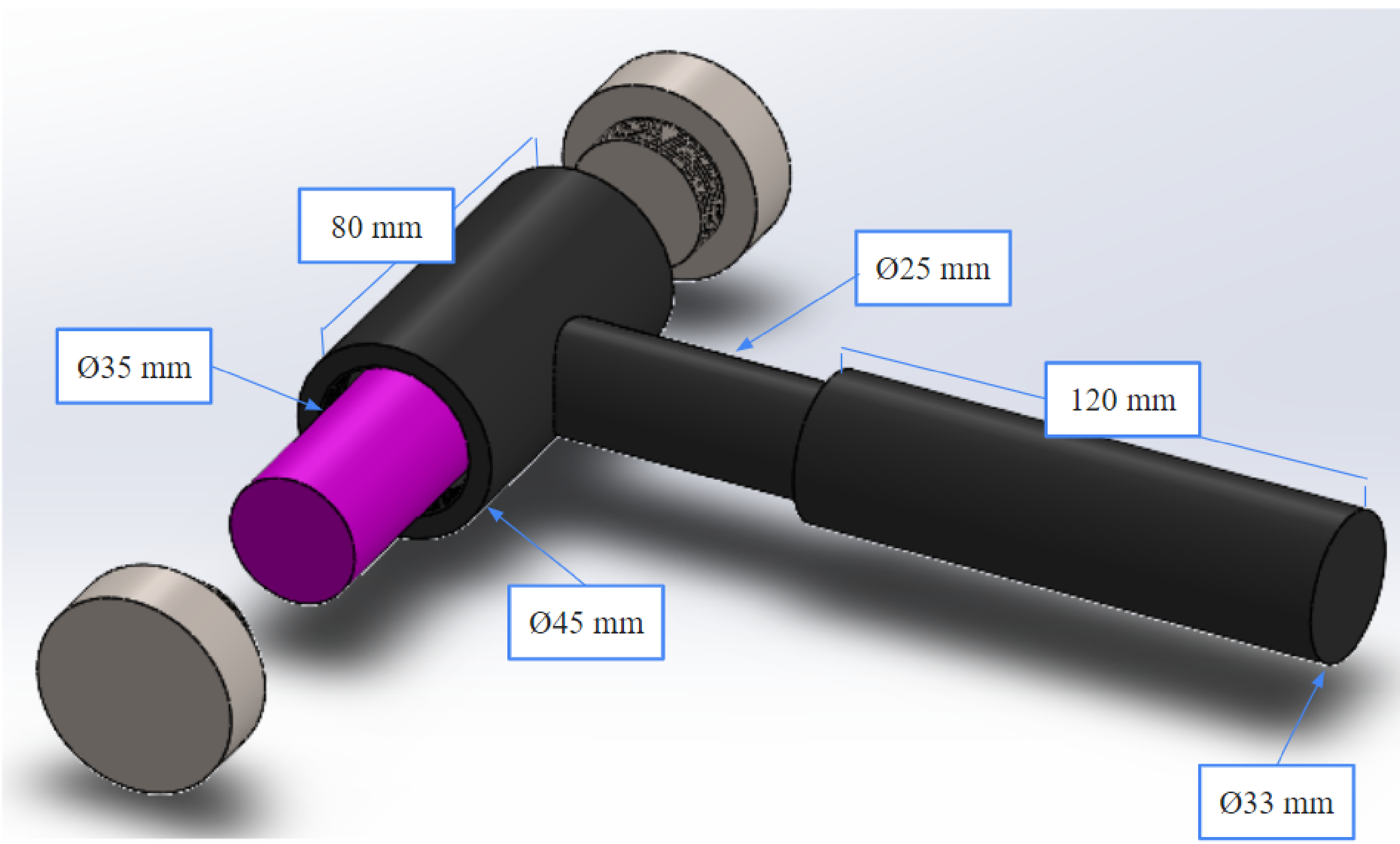


*Figure 1: Redesign of the mallet. This takes into consideration maximizing ergonomic comfort for the surgeon.*

<u>Calculations for the New Dimensions:</u>

Figure 2 shows the calculations for the maximum stresses that will occur. These stresses occur as (1) a normal stress in the shaft where the chamber occurs due to the thin wall (10 mm) and (2) a shear stress in the thinnest part of the handle.

## Stress Calculations (10/24 design)

$\sigma = \frac{F}{A}$

- Inner chamber

$A = \pi R_o^2 - \pi r_i^2 = \pi(45^2 - 35^2) = 800\pi \ mm^2$

$F_{max} = 40{,}000 \ N$ (w/ 1.5 FoS)

$\sigma_{max} = \frac{40{,}000 \ N}{800\pi \ mm^2} = 15.92 \ MPa = \sigma_{max}$ (inner chamber)

- With yield stresses as follows:
  - ss 303 a → $\sigma_y = 240 \ MPa$
  - ss 316L a → $\sigma_y = 205 \ MPa$
  - ss 316 a → $\sigma_y = 205 \ MPa$

This design fits well under the material physical constraints

- Shear in small Ø of handle:

$\tau_{max} = \frac{3}{2} \cdot \frac{V_{max}}{A}$

$A = \pi r^2 = \pi(25)^2 = 625\pi \ mm^2$

$V_{max} = 40{,}000 \ N$

$\tau_{max} = \frac{3}{2} \cdot \frac{40{,}000}{625\pi} = 30.56 \ MPa = \tau_{max}$ (handle)

*Figure 2: Calculations for the maximum stresses.*

The calculated theoretical stresses are as follows:

(1) The Shaft: The maximum normal stress is 15.92 MPa

(2) The Handle: The maximum shear stress is 30.56 MPa

Compared with the yield stresses of 303 annealed stainless steel (240 MPa) and 316/316L annealed stainless steel (205 MPa), these dimensions fit within the design constraints with a comfortable margin of error.

**Conclusions/action items:**

The team can move forward with these dimensions for testing.

WILLIAM BROWN - Dec 15, 2021, 9:01 AM CST

**Hammer_Shell.SLDPRT(394.5 KB) - download**

WILLIAM BROWN - Dec 15, 2021, 9:01 AM CST

**Mallet_Assembly.SLDASM(598.8 KB) - download**

# Expenses Table

WILLIAM BROWN - Dec 15, 2021, 9:29 AM CST

**Expense_Table.docx(7.1 KB) - download**

# 2021/11/25- 3D printed design and beads

**Title:** Discuss the 3D printed mallet

**Date:** 11/25/2021

**Content by:** Connor Link

**Goals:** Discuss the 3D printed mallet

**Sources:** [1] B. Wittbrodt and J. M. Pearce. "The Effects of PLA Color on Material Properties of 3-D Printed Components," *Additive Manufacturing*. 2015. [Online]. Available at: <https://www.researchgate.net/publication/283985639_The_Effects_of_PLA_Color_on_Material_Properties_of_3-D_Printed_Components> (Accessed 16 Nov. 2021).

**Content:**

Materials/Calculations:

The first iteration of the mallet was printed at the UW-Madison Makerspace with PLA plastic. This cost $10.96 for materials. After printing, the mallet was weighed and found to be 107 grams.

The color black was used for the dead blow mallet. The average yield strength is 49.23 +/- 1.18 MPa as reported by Wittbrodt and Pearce [1]. This is sufficient for the various dimensions of the Redesigned Handle").

Pictures:

Figure 1 contains two images for the mallet as printed with PLA plastic.

*Figure 1: Images of the dead blow mallet. The end caps are sealed with epoxy to ensure they do not come apart during testing.*

Filling/Masses

The measured mass of the hammer components (shaft with handle, end caps) was 107 grams. In order to fill the chamber by 50%, 306 beads are required (actually 50.6%). With a mass of 0.: as well.

**Conclusions/action items:**

With a mass that is equal to the empty hammer, conclusions from the testing procedure should be carefully considered. Analyzing the differences in maximum force produced does not tell us r
significance of the difference in impact time when compared to the control mallet.

# 2021/12/05 Testing Protocol

WILLIAM BROWN - Dec 15, 2021, 9:06 AM CST

**Title: Force Plate Testing Protocol**

**Date:** 12/5/21

**Content by:** Team

**Present:** Team

**Goals:** To describe the testing protocol to be used in testing.

**Content:**

**Dead-Blow Hammer Force Testing Protocol:**

**Materials Needed:**

- Dead blow mallet with steel beads (test)
- Regular mallet w/o dead blow media (control)
- Force plate
- Ruler

**Procedure:**

1. Assemble the dead blow mallet by placing the steel beads in the open space. Seal the end caps of both the dead blow mallet and the control mallet.
2. Set up a ruler for consistent striking. The mallet will be brought up to 0.3 meters (1 foot) before each strike.
3. Prepare the force plate for data collection. Ensure that the force reads zero when no loads are applied.
4. Begin data collection on (Bertec Force plate).
5. Strike the surface of the force plate with the control mallet three consecutive times without stopping in between. Ensure that the mallet is brought back up to the height of the ruler before every strike.
6. Stop data collection.
7. Repeat steps 3-6 for a total of five separate times. Attempt to keep the striking force consistent with each test. This should be at approximately 10% of maximum striking force (for a force of approximately 3-4 kN).
8. Repeat steps 3-7 with the dead blow mallet.
9. Collect all tests and analyze in Matlab

**Notes:**

- A total of 10 tests will be performed with 3 strikes each.
- This should not take more than 15 minutes once all items are prepared
- The striking force will be below 4 kN as the mallets in this test are PLA plastic prototypes
    - The goal is to keep the strikes consistent. One individual will perform all the tests.

**Conclusions/action items:**

This was the team's total protocol that was sent to professor Cone to be approved for force plate testing.

WILLIAM BROWN - Dec 15, 2021, 9:05 AM CST

**Testing_Protocol.docx(7.3 KB) - download**

# 2021/12/08- Force Testing Results/Analysis

WILLIAM BROWN - Dec 15, 2021, 9:00 AM CST

**Title:** Analysis of the Force-Time testing data that occurred on 12/7/2021

**Date:** 12/8/2021

**Content by:** Connor Link

**Goals:** Use Matlab to analyze the data in the force plate testing

**Content:**

Equations/Matlab Code Explanation

The data is presented as forces in the x, y, and z directions with a column containing each frame of data collection. With a collection frequency of 1000 Hz, data is sampled with a reading at every 0.001 seconds (meaning each row in the CSV file occurs every 0.001 seconds). In order to determine the force, the magnitude of all three force directions was calculated with Equation 1:

F_resultant = (Fx^2 + Fy^2 + Fz^2)^0.5 (Equation 1)

Since each test contained 3 consecutive strikes, the maximum force of each strike was centered so that 0.8 seconds of data was captured for each individual strike. This totaled 15 strikes for the dead blow mallet and 15 strikes for the control mallet. These values for resultant force were placed into a CSV file ("ResultantForce.csv" as attached) for ease of analysis in the future using code provided in "deadblow.m" (as attached).

The code titled "singlePeaks.m" (as attached) was used to create plots and perform statistical analysis on the data. This is presented below.

Results

Figure 1 contains a force-time plot with a total of 15 strikes by the control mallet. Figure 2 contains the force-time plot with a total of 15 strikes by the dead blow mallet.

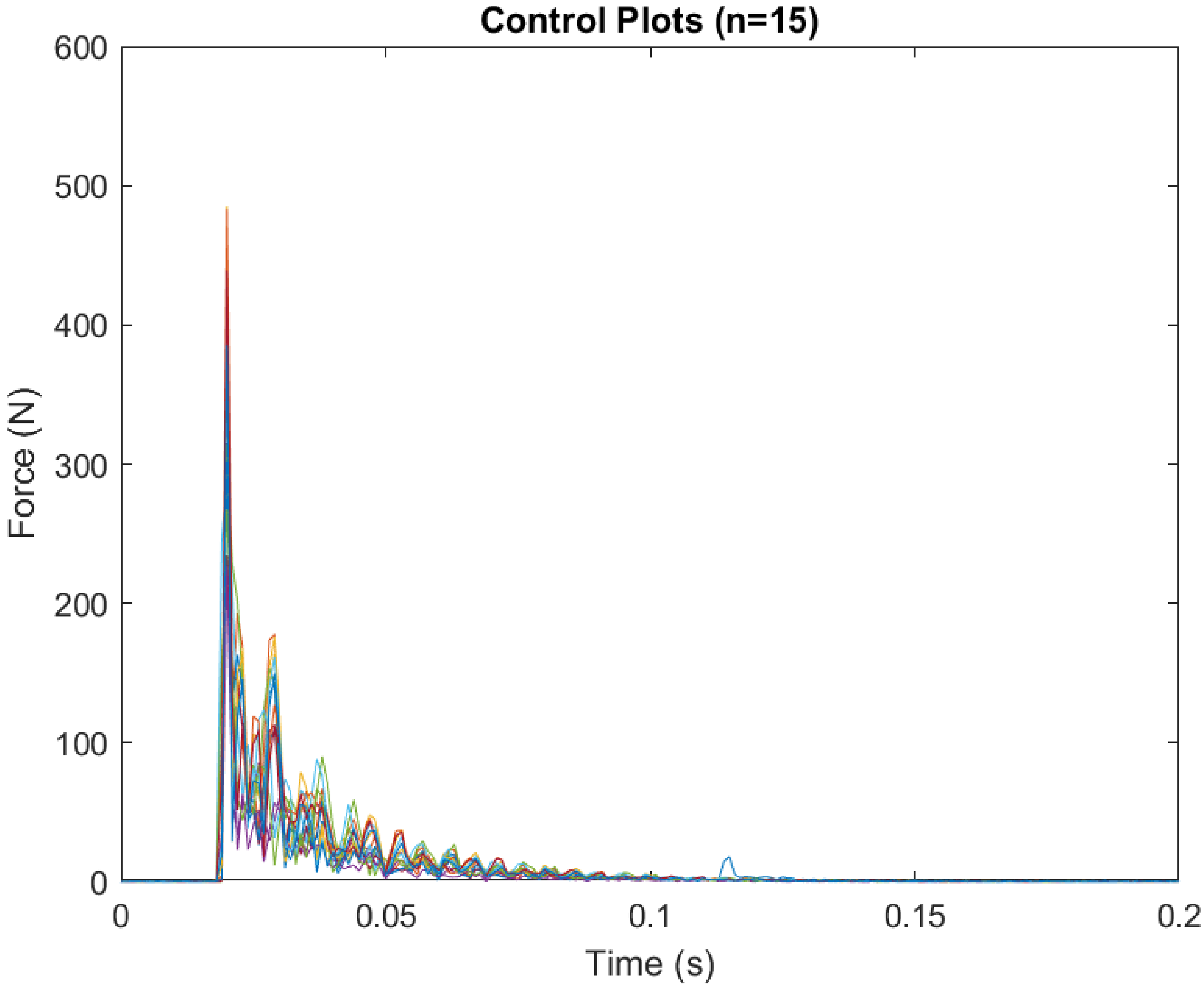


*Figure 1: Force-time plot for the control mallet.*

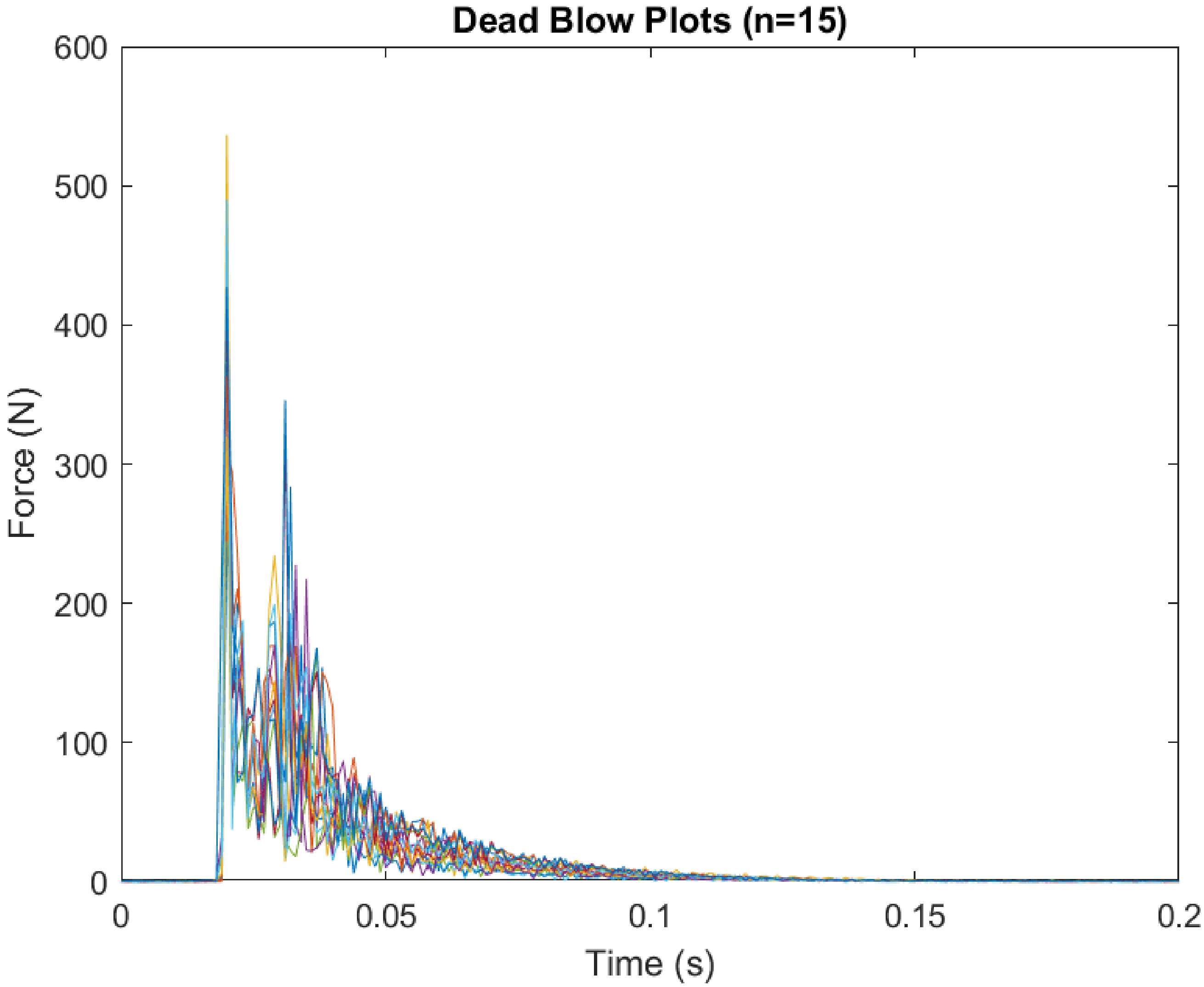


*Figure 2: Force-time plot for the dead blow mallet.*

Through visual inspection of Figure 1 and Figure 2, it appears that the dead blow mallet generally achieves a greater maximum force upon impact. However, with the weight differences and from the crude testing procedure, no conclusions can be made with confidence about the cause of this difference.

Figure 3 contains a force-time plot for the average values of all strikes for both the control and dead blow mallets. Figure 4 is a similar plot to Figure 3, however, each of the values in the plot are normalized for the maximum striking force that the test achieved (by dividing the value by the maximum force).

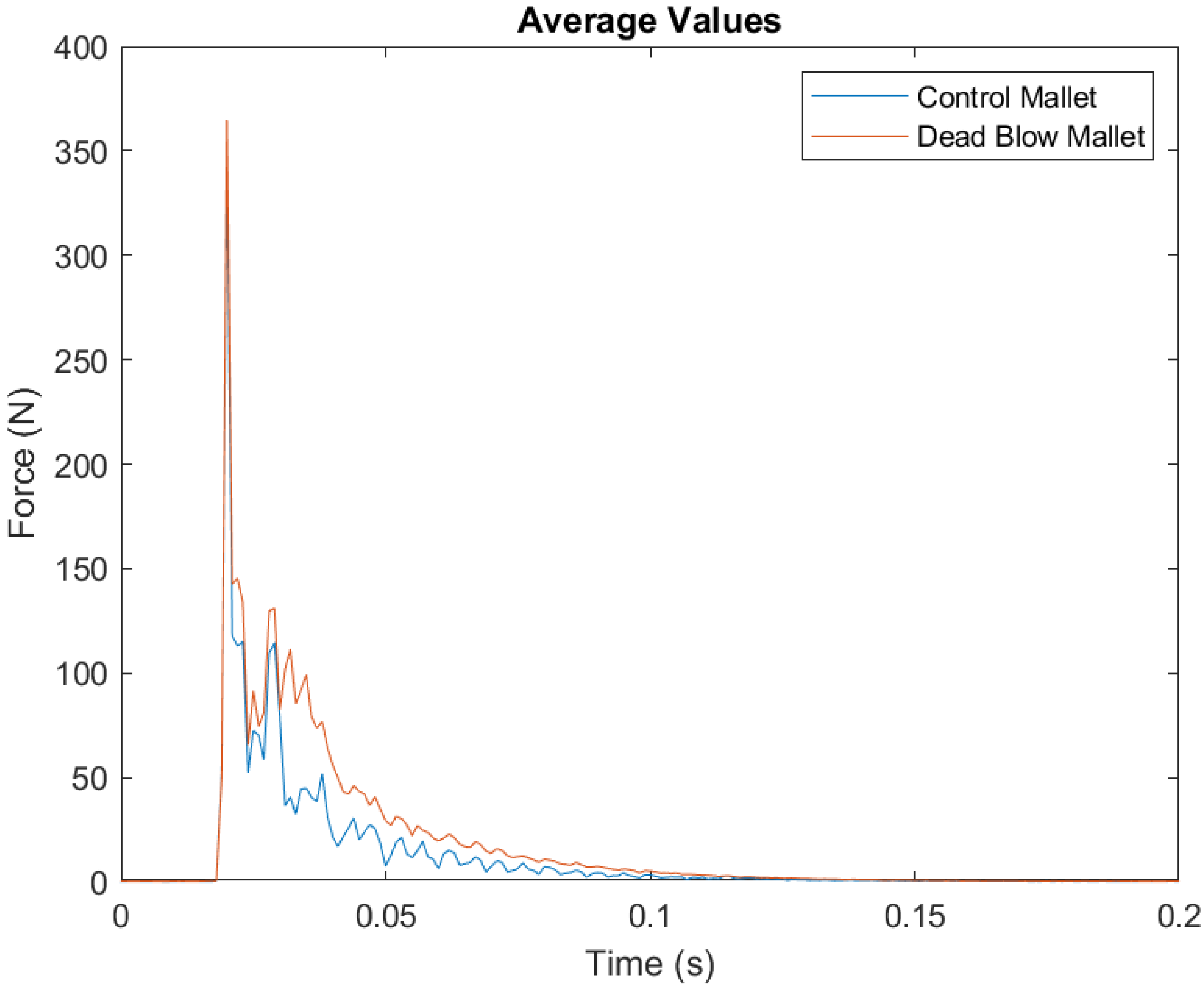


*Figure 3: Force-time plot for the average force characteristics of both the dead blow and control mallets during testing*

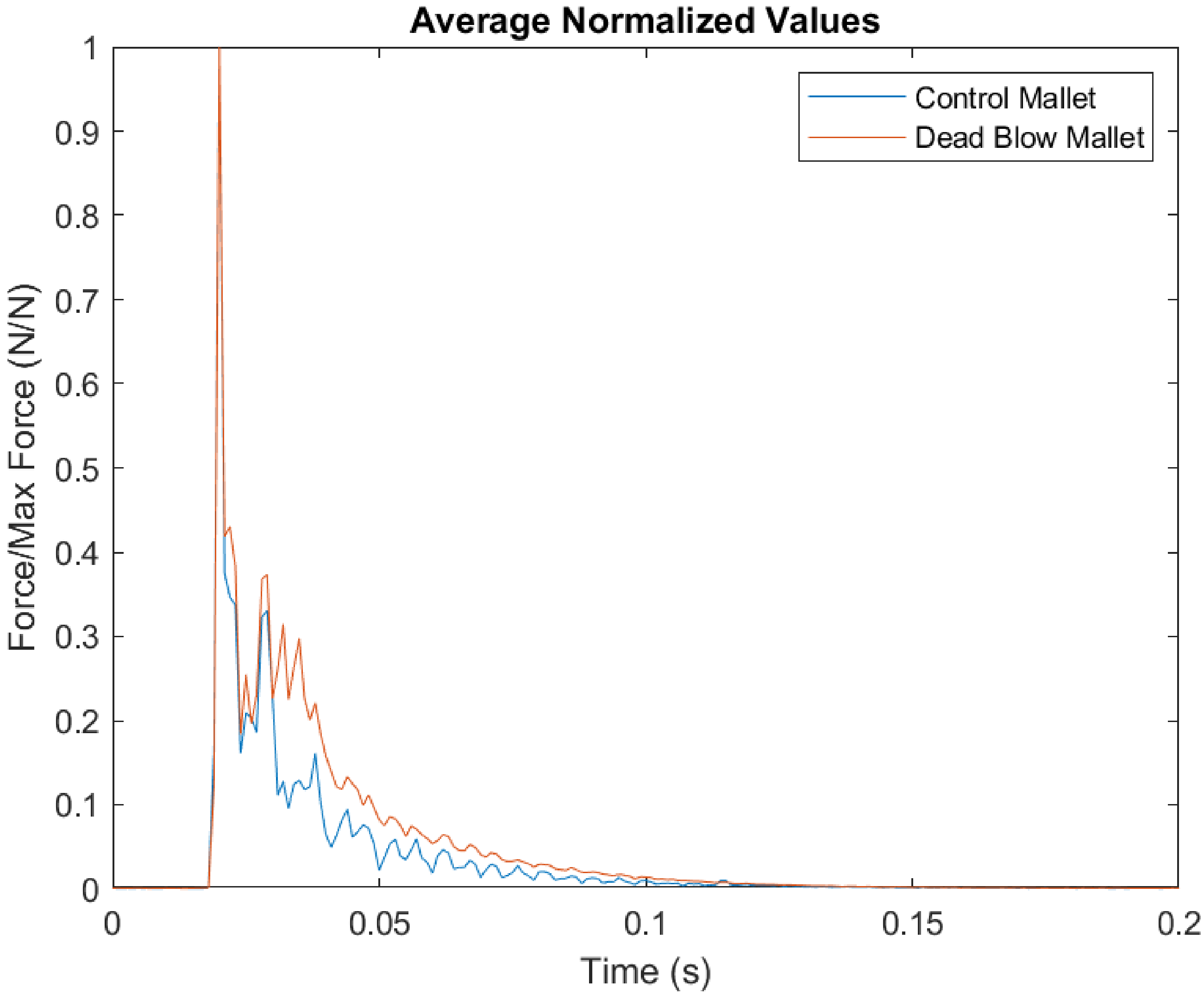


*Figure 4: Force-time plot for the average normalized force characteristics of both the dead blow and control mallets.*

Through visual inspection of Figures 3 and 4, it can be seen that the dead blow mallet appears to have a longer time of appreciable impact. This is further discussed with statistical analysis methods below.

Statistical Analysis

The impact time for each test was calculated by finding for how many seconds the force was over 5N of force for each test. The mean (+/- the standard deviation) for the control mallet was 0.061 +/- 0.007 seconds and for the dead blow mallet was 0.077 +/- 0.009 seconds.

A two-tailed t-test was performed to determine any significance between the difference of mean impact times. A p-value of approximately 1e-5 was returned through Matlab. This indicates that the dead blow impact time lasted longer than the control mallet, which aligns with our hypothesis.

**Conclusions/action items:**

The impact time was found to be significantly different between the two groups through a two-tailed t-test. This gives confidence in our current design dimensions, however, further testing with a metal mallet is required before any significant conclusions can be made. This will occur early in the Spring 2022 semester.

WILLIAM BROWN - Dec 15, 2021, 9:00 AM CST

**deadblow.m(1.4 KB) - download**

WILLIAM BROWN - Dec 15, 2021, 9:00 AM CST

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**singlePeaks.m(6.6 KB) - download**

WILLIAM BROWN - Dec 15, 2021, 9:00 AM CST

,

**ResultantForce.csv(444.7 KB) - download**

# 12/8/21 Testing Videos

WILLIAM BROWN - Dec 15, 2021, 9:17 AM CST

**Title: Lab Archives testing Videos**

**Date:** 12/8/21

**Content by:** William Brown

**Present:** Team

**Goals:** Upload testing videos.

**Content:**

Not all the videos are supplied here, some where to large to attach, but all of these videos were taken during the testing in the team lab following the procedure below.

**Dead-Blow Hammer Force Testing Protocol:**

**Materials Needed:**

- Dead blow mallet with steel beads (test)
- Regular mallet w/o dead blow media (control)
- Force plate
- Ruler

**Procedure:**

1. Assemble the dead blow mallet by placing the steel beads in the open space. Seal the end caps of both the dead blow mallet and the control mallet.
2. Set up a ruler for consistent striking. The mallet will be brought up to 0.3 meters (1 foot) before each strike.
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4. Begin data collection on (Bertec Force plate).
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6. Stop data collection.
7. Repeat steps 3-6 for a total of five separate times. Attempt to keep the striking force consistent with each test. This should be at approximately 10% of maximum striking force (for a force of approximately 3-4 kN).
8. Repeat steps 3-7 with the dead blow mallet.
9. Collect all tests and analyze in Matlab

**Notes:**

- A total of 10 tests will be performed with 3 strikes each.
- This should not take more than 15 minutes once all items are prepared
- The striking force will be below 4 kN as the mallets in this test are PLA plastic prototypes
    - The goal is to keep the strikes consistent. One individual will perform all the tests.

**Conclusions/action items:**

Will will likely use a different sort of image capture to test angles of deflection next semester.

WILLIAM BROWN - Dec 15, 2021, 9:17 AM CST

**IMG_2786.MOV(23.4 MB) - download**

WILLIAM BROWN - Dec 15, 2021, 9:17 AM CST

**IMG_2784.MOV(24.1 MB) - download**

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WILLIAM BROWN - Dec 15, 2021, 9:17 AM CST

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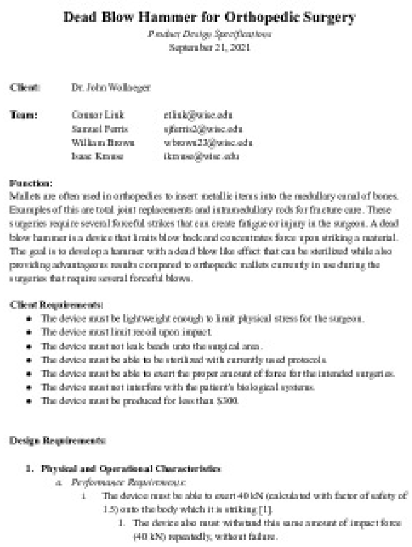
**IMG_2774.MOV(5.4 MB) - download**

WILLIAM BROWN - Dec 15, 2021, 9:17 AM CST

**IMG_2773.MOV(11.4 MB) - download**

# Product Design Specifications

SAMUEL FERRIS - Oct 20, 2021, 9:11 AM CDT



**Dead Blow Hammer for Orthopedic Surgery**

*Product Design Specifications*

September 21, 2021

**Client:** Dr. John Wollaeger

**Team:**
Connor Link clink@wisc.edu
Samuel Ferris sjferris2@wisc.edu
William Brown wbrown22@wisc.edu
Isaac Krause ikrause@wisc.edu

**Function:**

Mallets are often used in orthopedics to insert metallic items into the medullary canal of bones. Examples of this are total joint replacements and intramedullary rods for fracture care. These surgeries require several forceful strikes that can create fatigue or injury in the surgeon. A dead blow hammer is a device that limits blow back and concentrates force upon striking a material. The goal is to develop a hammer with a dead blow like effect that can be sterilized while also providing advantageous results compared to orthopedic mallets currently in use during the surgeries that require several forceful blows.

**Client Requirements:**

- The device must be lightweight enough to limit physical stress for the surgeon.
- The device must limit recoil upon impact.
- The device must not leak beads unto the surgical area.
- The device must be able to be sterilized with currently used protocols.
- The device must be able to exert the proper amount of force for the intended surgeries.
- The device must not interfere with the patient's biological systems.
- The device must be produced for less than $300.

**Design Requirements:**

1. **Physical and Operational Characteristics**
    a. *Performance Requirements:*
        i. The device must be able to exert 40 kN (calculated with factor of safety of 1.5) onto the body which it is striking [1].
            1. The device also must withstand this same amount of impact force (40 kN) repeatedly, without failure.

**Product_Design_Specifications.pdf(112.5 KB) - download**

# Design Matrix/Criteria

WILLIAM BROWN - Dec 15, 2021, 9:26 AM CST

**Design_Matrix_Criteria_BME_400.docx(438.1 KB) - download**

# Preliminary Report

WILLIAM BROWN - Dec 15, 2021, 9:24 AM CST

**Preliminary_Report.docx(1.4 MB) - download**

# Preliminary Presentation

WILLIAM BROWN - Dec 15, 2021, 9:25 AM CST

**_Preliminary_Presentation.pptx(3.2 MB) - download**

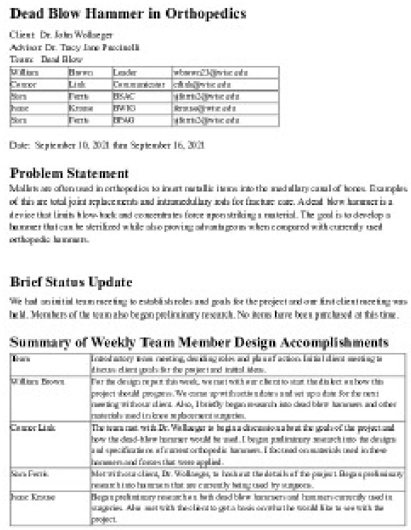
# Final Team Poster

WILLIAM BROWN - Dec 15, 2021, 9:18 AM CST

**Dead_Blow_Final_Poster.pptx(1.2 MB) - download**

# Progress Report 1

SAMUEL FERRIS - Oct 20, 2021, 9:22 AM CDT



## Dead Blow Hammer in Orthopedics

Client: Dr. John Wollaeger
Advisor: Dr. Tracy Jane Puccinelli
Team: Dead Blow

| | | | |
|---|---|---|---|
| William | Brown | Leader | wbrown23@wisc.edu |
| Connor | Link | Communicator | cflink@wisc.edu |
| Sam | Ferris | BSAC | sjferris2@wisc.edu |
| Isaac | Krause | BWIG | ikrause@wisc.edu |
| Sam | Ferris | BPAG | sjferris2@wisc.edu |

Date: September 10, 2021 thru September 16, 2021

### Problem Statement

Mallets are often used in orthopedics to insert metallic items into the medullary canal of bones. Examples of this are total joint replacements and intramedullary rods for fracture care. A dead blow hammer is a device that limits blow-back and concentrates force upon striking a material. The goal is to develop a hammer that can be sterilized while also proving advantageous when compared with currently used orthopedic hammers.

### Brief Status Update

We had an initial team meeting to establish roles and goals for the project and our first client meeting was held. Members of the team also began preliminary research. No items have been purchased at this time.

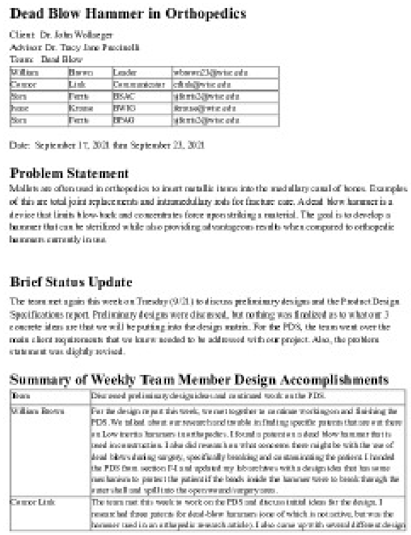
### Summary of Weekly Team Member Design Accomplishments

| | |
|---|---|
| Team | Introductory team meeting, deciding roles and plan of action. Initial client meeting to discuss client goals for the project and initial ideas. |
| William Brown | For the design report this week, we met with our client to start the thinking on how this project should progress. We came up with tentative dates and set up a date for the next meeting with our client. Also, I briefly began research into dead blow hammers and other materials used in knee replacement surgeries. |
| Connor Link | The team met with Dr. Wollaeger to begin a discussion about the goals of the project and how the dead-blow hammer would be used. I began preliminary research into the designs and specifications of current orthopedic hammers. I focused on materials used in these hammers and forces that were applied. |
| Sam Ferris | Met with our client, Dr. Wollaeger, to hash out the details of the project. Began preliminary research into hammers that are currently being used by surgeons. |
| Isaac Krause | Began preliminary research on both dead blow hammers and hammers currently used in surgeries. Also met with the client to get a basis on what he would like to see with the project. |

**Progress_Report_9_16_2021_.pdf(85.8 KB) - download**

# Progress Report 2

SAMUEL FERRIS - Oct 20, 2021, 9:22 AM CDT



## Dead Blow Hammer in Orthopedics

Client: Dr. John Wollaeger
Advisor: Dr. Tracy Jane Puccinelli
Team: Dead Blow

| | | | |
|---|---|---|---|
| William | Brown | Leader | wbrown23@wisc.edu |
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| Sam | Ferris | BSAC | sjferris2@wisc.edu |
| Isaac | Krause | BWIG | ikrause@wisc.edu |
| Sam | Ferris | BPAG | sjferris2@wisc.edu |

Date: September 17, 2021 thru September 23, 2021

### Problem Statement

Mallets are often used in orthopedics to insert metallic items into the medullary canal of bones. Examples of this are total joint replacements and intramedullary rods for fracture care. A dead blow hammer is a device that limits blow-back and concentrates force upon striking a material. The goal is to develop a hammer that can be sterilized while also providing advantageous results when compared to orthopedic hammers currently in use.

### Brief Status Update

The team met again this week on Tuesday (9/21) to discuss preliminary designs and the Product Design Specifications report. Preliminary designs were discussed, but nothing was finalized as to what our 3 concrete ideas are that we will be putting into the design matrix. For the PDS, the team went over the main client requirements that we knew needed to be addressed with our project. Also, the problem statement was slightly revised.

### Summary of Weekly Team Member Design Accomplishments

| | |
|---|---|
| Team | Discussed preliminary design ideas and continued work on the PDS. |
| William Brown | For the design report this week, we met together to continue working on and finishing the PDS. We talked about our research and trouble in finding specific patents that are out there on Low inertia hammers in orthopedics. I found a patent on a dead blow hammer that is used in construction. I also did research on what concerns there might be with the use of dead blows during surgery, specifically breaking and contaminating the patient. I handled the PDS from section F4 and updated my [illegible] with a design idea that has some mechanism to protect the patient if the beads inside the hammer were to break through the outer shell and spill into the open wound/surgery area. |
| Connor Link | The team met this week to work on the PDS and discuss initial ideas for the design. I researched three patents for dead-blow hammers (one of which is not active, but was the hammer used in an orthopedic research article). I also came up with several different design |

**Progress_Report_9_23_21_.pdf(89.2 KB) - download**

# Progress Report 3

SAMUEL FERRIS - Oct 20, 2021, 9:22 AM CDT

## Dead Blow Hammer in Orthopedics

Client: Dr. John Wollaeger
Advisor: Dr. Tracy Jane Puccinelli
Team: Dead Blow

| | | | |
|---|---|---|---|
| William | Brown | Leader | wbrown23@wisc.edu |
| Connor | Link | Communicator | cflink@wisc.edu |
| Sam | Ferris | BSAC | sjferris2@wisc.edu |
| Isaac | Krause | BWIG | ikrause@wisc.edu |
| Sam | Ferris | BPAG | sjferris2@wisc.edu |

Date: September 24, 2021 thru September 30, 2021

### Problem Statement

Mallets are often used in orthopedics to insert metallic items into the medullary canal of bones. Examples of this are total joint replacements and intramedullary rods for fracture care. A dead blow hammer is a device that limits blow-back and concentrates force upon striking a material. The goal is to develop a hammer that can be sterilized while also providing advantageous results when compared to orthopedic hammers currently in use.

### Brief Status Update

After a client meeting (9/28) to check in and discuss design thoughts, the team met again on Wednesday (9/29) to discuss the design matrix for our three preliminary designs. The criteria was decided, the categories weighted, and the designs were given a score out of 5 possible points. The design that scored highest was the dead blow hammer with replaceable caps with an inner casing. We will be moving forward with this design in mind and will begin working on the upcoming preliminary presentation.

### Summary of Weekly Team Member Design Accomplishments

| | |
|---|---|
| Team | Discussed preliminary design ideas and continued work on the PDS. |
| William Brown | This week in the design process our team met with our client Dr. Wollaeger to go over our PDS and update him on the design ideas we had come up with. We talked about a testing protocol that our team might be able to get our hands on in order to test the hammer that Dr. Wollaeger uses currently. We also met as a team in order to complete our design matrix. My design 3 was chosen as the winning design after the team completed grading and justification. Lastly, I started working on slides for the presentation coming up. |
| Connor Link | This week I met with the team and the client. I also began research into material properties of metals and polymers that could be used for the design of the hammer. I searched the literature for forces generated by orthopedic surgeons during surgery and found some values. Unfortunately, the method used for this data collection requires purchasing a load |

**Progress_Report_9_30_21_.pdf(89.7 KB) - download**

# Progress Report 4

SAMUEL FERRIS - Oct 20, 2021, 9:26 AM CDT

## Dead Blow Hammer in Orthopedics

Client: Dr. John Wollaeger
Advisor: Dr. Tracy Jane Puccinelli
Team: Dead Blow

| | | | |
|---|---|---|---|
| William | Brown | Leader | wbrown23@wisc.edu |
| Connor | Link | Communicator | cflink@wisc.edu |
| Sam | Ferris | BSAC | sjferris2@wisc.edu |
| Isaac | Krause | BWIG | ikrause@wisc.edu |
| Sam | Ferris | BPAG | sjferris2@wisc.edu |

Date: October 1, 2021 thru October 7, 2021

### Problem Statement

Mallets are often used in orthopedics to insert metallic items into the medullary canal of bones. Examples of this are total joint replacements and intramedullary rods for fracture care. A dead blow hammer is a device that limits blow-back and concentrates force upon striking a material. The goal is to develop a hammer that can be sterilized while also providing advantageous results when compared to orthopedic hammers currently in use.

### Brief Status Update

After completing the design matrix last week, the model of Replaceable Caps was further refined. Modelling in Solidworks and material selection also began for this design. The team also began working on the preliminary design presentation which will take place on October 15.

### Summary of Weekly Team Member Design Accomplishments

| | |
|---|---|
| Team | Worked on research and the preliminary presentation. |
| William Brown | This week I looked into Testing methods for the hammer but could not find anything substantial. I also began work on the preliminary design presentation that is due next week. I also looked into whether ergonomics or effectiveness better define the process of limiting the blow of the hammer. I came to the conclusion that the limiting blow back can be incorporated into either category but will need to be explained in the presentation. |
| Connor Link | This week I began the initial solidworks model for the Replaceable Caps design. Before getting started, I calculated the stresses that the hammer would experience under a range of outer diameters (for the cap) and inner diameters (for the internal casing) that would occur under maximum reported force (~40 kN). I also looked into materials that have a yield stress greater than the calculated max stress. This is important because we do not want the mallet to undergo any plastic deformation during reasonable use by surgeons, as this would make the mallet unusable afterwards. |

**Progress_Report_10_7_21_.pdf(87.4 KB) - download**

# Progress Report 5

SAMUEL FERRIS - Oct 20, 2021, 9:26 AM CDT

## Dead Blow Hammer in Orthopedics

Client: Dr. John Wollaeger
Advisor: Dr. Tracy Jane Puccinelli
Team: Dead Blow

| | | | |
|---|---|---|---|
| William | Brown | Leader | wbrown23@wisc.edu |
| Connor | Link | Communicator | cflink@wisc.edu |
| Sam | Ferris | BSAC | sjferris2@wisc.edu |
| Isaac | Krause | BWIG | ikrause@wisc.edu |
| Sam | Ferris | BPAG | sjferris2@wisc.edu |

Date: October 8, 2021 thru October 14, 2021

### Problem Statement

Mallets are often used in orthopedics to insert metallic items into the medullary canal of bones. Examples of this are total joint replacements and intramedullary rods for fracture care. A dead blow hammer is a device that limits blow-back and concentrates force upon striking a material. The goal is to develop a hammer that can be sterilized while also providing advantageous results when compared to orthopedic hammers currently in use.

### Brief Status Update

The preliminary design presentation slides were finalized and the team spent the week practicing each of our parts for the presentation on Friday. The first iteration of the mallet design was also completed in Solidworks.

### Summary of Weekly Team Member Design Accomplishments

| | |
|---|---|
| Team | Preliminary presentation complete and practiced individual parts. |
| William Brown | This week I finished the design presentation after meeting with Dr. TJP. I practiced for the presentation. |
| Connor Link | This week I finished the preliminary design for the Replaceable Caps design in Solidworks. I used Matlab to determine an optimal inner diameter given the outer diameter of 40 mm for the head. I also helped finalize the preliminary design report. |
| Sam Ferris | Finished and edited the preliminary design after hearing feedback from Tracy. |
| Isaac Krause | The same as the rest of my teammates. Completed and made edits to the preliminary report and began practicing for the presentation on Friday. |

### Weekly/Ongoing Difficulties

*Nothing so far.*

**Progress_Report_10_14_21_.pdf(85.9 KB) - download**

# Progress Report 6

WILLIAM BROWN - Dec 15, 2021, 9:20 AM CST

**Progress_Report_10_21_21_.docx(11.4 KB) - download**

# Progress Report 7

WILLIAM BROWN - Dec 15, 2021, 9:21 AM CST

**Progress_Report_10_28_21_.docx(11.7 KB) - download**

# Progress Report 8

WILLIAM BROWN - Dec 15, 2021, 9:21 AM CST

**Progress_Report_11_4_21_.docx(11.8 KB) - download**

# Progress Report 9

WILLIAM BROWN - Dec 15, 2021, 9:22 AM CST

**Progress_Report_11_11_21_.docx(12 KB) - download**

# Progress Report 10

WILLIAM BROWN - Dec 15, 2021, 9:22 AM CST

**Progress_Report_11_18_21_.docx(11.8 KB) - download**

# Progress Report 11

WILLIAM BROWN - Dec 15, 2021, 9:22 AM CST

**Progress_Report_12_2_21_.docx(12.1 KB) - download**

# Progress Report 12

WILLIAM BROWN - Dec 15, 2021, 9:23 AM CST

**Progress_Report_12_9_21_.docx(11.4 KB) - download**

# 2021/09/21-Knee Replacement Video

WILLIAM BROWN - Sep 23, 2021, 11:49 AM CDT

**Title: Knee Replacement Video**

**Date:** 2021/09/21

**Content by:** William Brown

**Present:** William Brown

**Goals:** To provide the video of our knee replacements.

**Content:** I cannot figure out how to embed the video into the lab archive but this is the link to watch the video on youtube. The major thing with skimming through this video was the fact that surgeons are not gentle. They have to smash with the hammer. Reinforcing the idea that our hammer must be durable. (major points in design matrix)

https://youtu.be/JzMCGf6_ipY

**Conclusions/action items:**

I think that this video is so cool and reminds me of the times I have watched other doctors and also reminds me of my own surgery. I think that the durability of our hammer must be very import and will have a large weight in our design matrix

# 2021/09/23- PDS research

WILLIAM BROWN - Sep 23, 2021, 4:38 PM CDT

**Title:** PDS Research

**Date:** 9/23/21

**Content by:** William Brown

**Present:** William Brown

**Goals:** To do some research for objects F-I in the PDS

**Content:**

The first reference is mentioning the typical autoclave temperature needed for sterilization. This was found to be 121 degrees celsius.

The second reference is looking at different mallets that are used now to base our size dimensions on. The dimensions of the two mallets below are 8 inches and weight of 1-1.75 lbs. The head diameter of the mallets ranges from 1 5/16th inch- 1 1/2 inches.

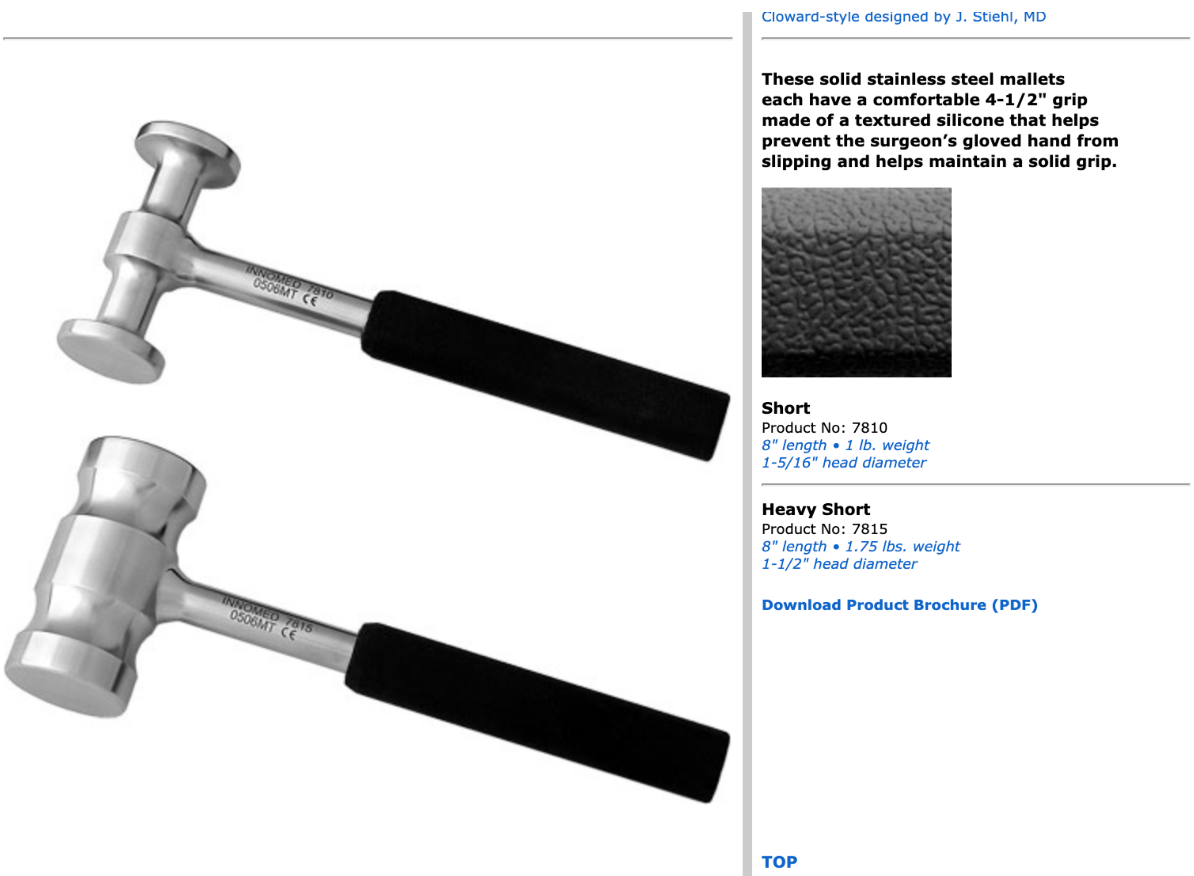



Figure 1: This image above is from [innomed.net](innomed.net) and is showing the dimensions described above. These are mallets that are used in orthopedic surgeries.

Both the next two references mention standard atmospheric pressure and temperature that our tool should be able to stand.

**[1] "Autoclave Use." https://ehs.princeton.edu/book/export/html/380 (accessed Sep. 23, 2021).**

**[2] "Innomed Knee Instruments — extraction & revision – other useful instruments." http://www.innomed.net/knee_ex_other.htm#Anchor-Ortho-363 (accessed Sep. 22, 2021).**

[3] M. Cavcar, "The International Standard Atmosphere (ISA)," p. 7.

[4] "3.6 Understanding the Atmosphere's Temperature Profile," *METEO 300: Fundamentals of Atmospheric Science*. [Online]. Available: https://www.e-education.psu.edu/meteo300/node/594#:~:

**Conclusions/action items:**

This is basically used to document the research done on the PDS for my section.

# 10/14/21 Grip Material

WILLIAM BROWN - Oct 19, 2021, 9:53 PM CDT

**Title:** Grip Material

**Date:** 10/19/21

**Content by:** William Brown

**Present:** Me

**Goals:** To describe the grip material that could be used in our design.

**Content:**

Apon research, there are not many common materials used for griping surgical devices. The gloves that are used, latex, Polyisoprene or Nitrile, provide enough grip for the surgeon to perform most surgical operations [1]. There are options for grip additions that could be put onto the device before operations but that removed and discarded after surgery. This seems like a needless addition after our client has not mentioned an issue with the grip of his existing model. Something that I could look into more in the future would be adding groves to the bottom on the handle to add mechanical grip. This could perhaps lead to bacteria build-up.

**Conclusions/action items:**

This is good to know that grip is likely not necessary in the project.

[1] “Surgical gloves | DermNet NZ.” https://dermnetnz.org/topics/surgical-gloves (accessed Oct. 19, 2021).

# 10/19/21 Stainless Steel research

WILLIAM BROWN - Oct 20, 2021, 8:45 AM CDT

**Title:** Materials Used for Surgical instruments

**Date:** 10/19/21

**Content by:** William

**Present:** Me

**Goals:** To describe some common alloys used in surgical instruments

**Content:**

Stainless steel is an alloy that incorporates Pure Iron, Carbon, Chromium. The residual elements that are kept from the starting material are Nickel magnesium silicon molybdenum and sulfur. These residual elements may be taken out if specified in the present composition of the steel [1].

A very popular type of steel is Stainless Steel 304. This is the most common kind of stainless steel but stainless steel 316 is used more often in the medical field. 316 has a slightly lower chromium percentage than 304 (-2%) but has an increase in nickel (2%) and an increase in molybdenum. This leads to more resistance to saltwater corrosion [1].

| Stainless Grade | Hardness (Rb)[1] | Tensile Strength (1000 psi)[2] | Yield Strength (0.2% 1000 psi)[3] | Elongation (% in 2")[4] |
|---|---|---|---|---|
| 304/316 | 78-83 | 80-85 | 30-42 | 50-60 |
| 430 | 80-85 | 70-75 | 40-50 | 30-35 |
| 410 | 80-82 | 70-75 | 34-45 | 25-35 |
| 409 | 75 | 65 | 35 | 25 |

Figure 1: The mechanical properties of different types of Stainless steel. [1]

As you can see in figure 1, 316 is still hard and strong. High tensile strength and adequate yield strength[1].

Stainless steel is perfect for medical operations for the fact that it is very easily cleaned, cost-effective and recyclable. The steps to clean stainless steel are as follows[1].

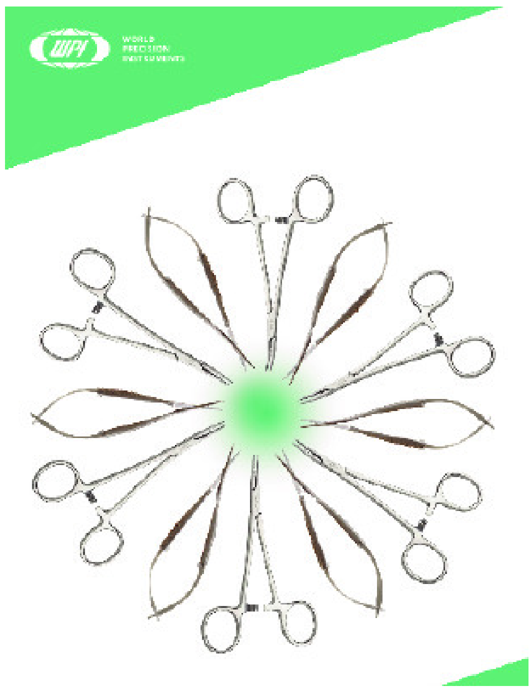
1. Rinse the tool right after use.
2. Manual cleaning (with stiff plastic cleaning brushes)
3. Ultrasonic cleaning (could be used)
4. Autoclaving: can be autoclaved to 180 degrees Celcius and is temperature resistant to 400 degrees Celcius.

[1] “Surgical Instruments, Surgical Tools | Surgical Instruments, Research Instruments, Laboratory Equipment | WPI.” https://www.wpiinc.com/surgical-instruments (accessed Oct. 19, 2021).

**Conclusions/action items:**

Stainless Steel will likely be used for the handle and hammer head. More research to be done with strong polymer for caps.

WILLIAM BROWN - Oct 20, 2021, 8:26 AM CDT



**MDI-Cleaning_IMs.pdf(7.4 MB) - download**

WILLIAM BROWN - Oct 20, 2021, 8:27 AM CDT

The PDF attachment is not mine. It is the resource that some of the information about materials comes from. I left it here for myself incase I would like to come back to it.

# 11/28/21 Physics of Dead Blow Hammer

WILLIAM BROWN - Dec 02, 2021, 12:15 PM CST

**Title:** Dead Blow Hammer Physics

**Date:** 11/28/21

**Content by:** William Brown

**Present:** Me

**Goals:** To describe the physics behind the dead blow hammer

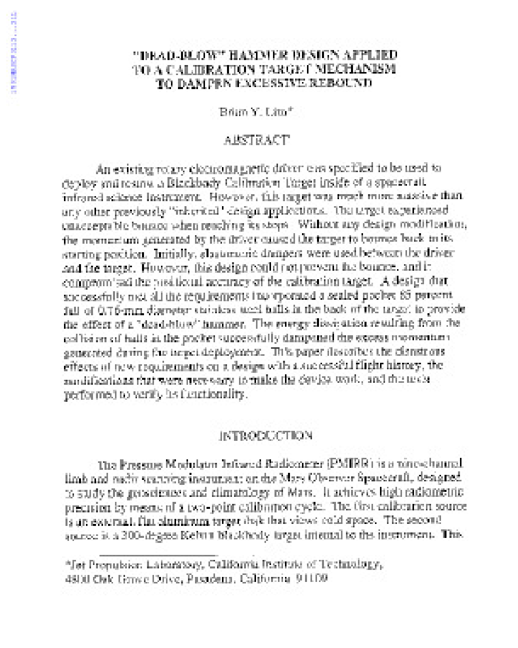
**Content:**

Dead blow hammers use metal shot inside of a hallow cavity to change limit the momentum of the hammer away from the target.  This scholarly article attached by Brian Y Lim goes through the testing of different bounce-back limiting devices and how they counteract the momentum. Lim describes the fact that a Dead-Blow hammer limited bounce-back most effectively in his testing. The mechanics of this is that each ball in the hollow cavity has a small momentum directed at the target immediately after sticking the target. This counter momentum opposes the momentum of the hammer away from the target in turn limiting the bounce effect. The kinetic energy of the hammer is counteracted by the sum of the momentum of each individual ball. Lim's hammer was filled with 0.76 mm balls that filled the hollow cavity 85 % full. Although Lim's hammer was slightly different than our model the same idea is still true.

**Conclusions/action items:**

How full we fill our design will hopefully be tested.

WILLIAM BROWN - Dec 02, 2021, 12:06 PM CST


"DEAD-BLOW" HAMMER DESIGN APPLIED
TO A CALIBRATION TARGET MECHANISM
TO DAMPEN EXCESSIVE REBOUND

Brian Y. Lim*

ABSTRACT

An existing rotary electromagnetic driver was specified to be used to deploy and restow a Blackbody Calibration Target inside of a spacecraft infrared science instrument. However, this target was much more massive than any other previously "inherited" design applications. The target experienced unacceptable bounce when reaching its stops. Without any design modification, the momentum generated by the driver caused the target to bounce back to its starting position. Initially, elastomeric dampers were used between the driver and the target. However, this design could not prevent the bounce, and it compromised the positional accuracy of the calibration target. A design that successfully met all the requirements incorporated a sealed pocket 85 percent full of 0.76-mm diameter stainless steel balls in the back of the target to provide the effect of a "dead-blow" hammer. The energy dissipation resulting from the collision of balls in the pocket successfully dampened the excess momentum generated during the target deployment. This paper describes the disastrous effects of new requirements on a design with a successful flight history, the modifications that were necessary to make the device work, and the tests performed to verify its functionality.

INTRODUCTION

The Pressure Modulator Infrared Radiometer (PMIRR) is a nine-channel limb and nadir scanning instrument on the Mars Observer Spacecraft, designed to study the atmosphere and climatology of Mars. It achieves high radiometric precision by means of a two-point calibration cycle. The first calibration source is an external, flat aluminum target disk that views cold space. The second source is a 300-degree Kelvin blackbody target internal to the instrument. This

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4800 Oak Grove Drive, Pasadena, California 91109

21

Lim_Brian.pdf(1.3 MB) - download

# 2021/09/17- Dead Blow outside of Ortho

WILLIAM BROWN - Sep 21, 2021, 9:45 AM CDT

Title: Dead Blow Hammer Uses

**Date:** 9/17/21

**Content by:** William Brown

**Present:** William Brown

**Goals:** To research uses of a dead blow hammer outside of orthopedics

**Content:**

"A dead blow hammer is a specialized mallet which absorbs tremors when the hammer strikes.

It is an extremely useful tool as it minimizes damage to a struck surface and its minimal rebound helps to avoid accidental damage to precision work, especially when working in tight areas." [1]

This is the opening description from the Teng Tools USA site that begins the research for this semester. To me, this quote explains the exact reason why a dead blow would be used in orthopedic surgeries. Both points about avoiding damage and being useful in tight areas are the correct ways to look at the benefits of this construction tool being used in surgeries.

This same site mentions that dead blow hammers should be used on small jobs like "chassis repair" and "flooring jobs".

"Unlike conventional hammers, a dead blow hammer can be prone to breaking if it is used to strike a hard surface with a lot of force." This is the major concern from reading the article and will need to be addressed in the PDS. Our client mentioned that a major concern would be if the hammer broke during an operation, which would be an issue and likely cause health problems for the patient.

1] "How To Use A Dead Blow Hammer– Teng Tools USA." https://tengtoolsusa.com/blogs/news/how-to-use-a-dead-blow-hammer (accessed Sep. 17, 2021).

**Conclusions/action items:**

This major concern and issue to look at is the last quote from the article earlier. The durability of the hammer will be a heavily weighted category in the score of our eventually design ideas. More research will be needed to discover more concerns related to the durabiltiy.

# 2021/09/17- Site for dead blow purchase

WILLIAM BROWN - Sep 21, 2021, 9:41 AM CDT

https://www.grainger.com/category/tools/hand-tools/hammers-striking-tools/dead-blow-hammers?cm_sp=CM-Shop-_-inline-text-_-kh-types-of-hammers-_-2019-09

This link is a site that we could buy a dead blow hammer from for testing, if necessary.

# 2021/09/21-Dead Blow Hammers Patent

WILLIAM BROWN - Sep 23, 2021, 10:45 AM CDT

**Title:** Patent for Dead Blow Hammer

**Date:** 9/21/21

**Content by:** William Brown

**Present:** William Brown

**Goals:** To document other patents on similar tools that are already present.

**Content:**

Attached is the patent documentation for a dead blow hammer. The image below is taken from the documentation showing the steel beads inside of the head of the hammer. This is the main component in limiting the rebound from the impact. **US7168338B2.** A few aspects that I enjoy about this mallet: The rounded tip and the inner shell/opening allowing the beads to move inside thus limiting blowback from a strike.

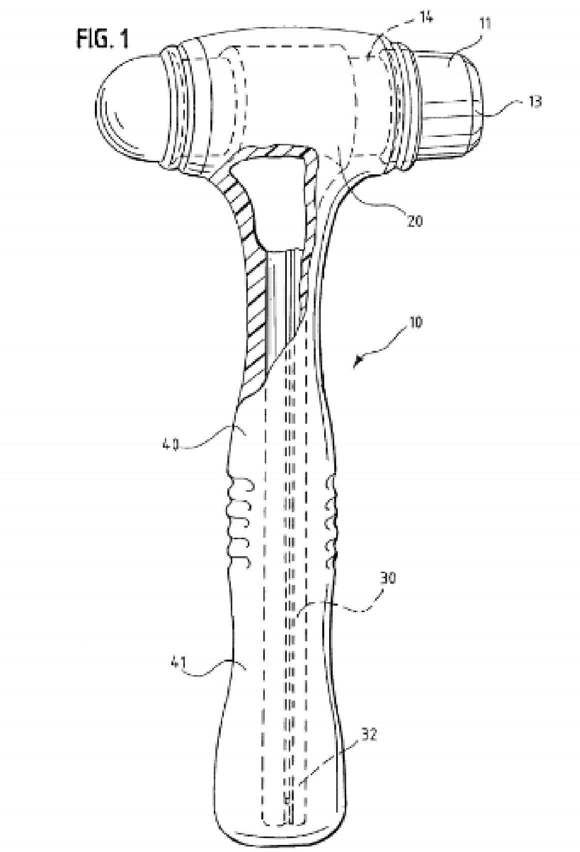



Figure 1: This complete dead blow hammer is shown with the outer casing that is used to provide grip and comfort for the person using it. The hammer has a tubular head with a cylindrical collar. (Figure is taken from the patent attached).

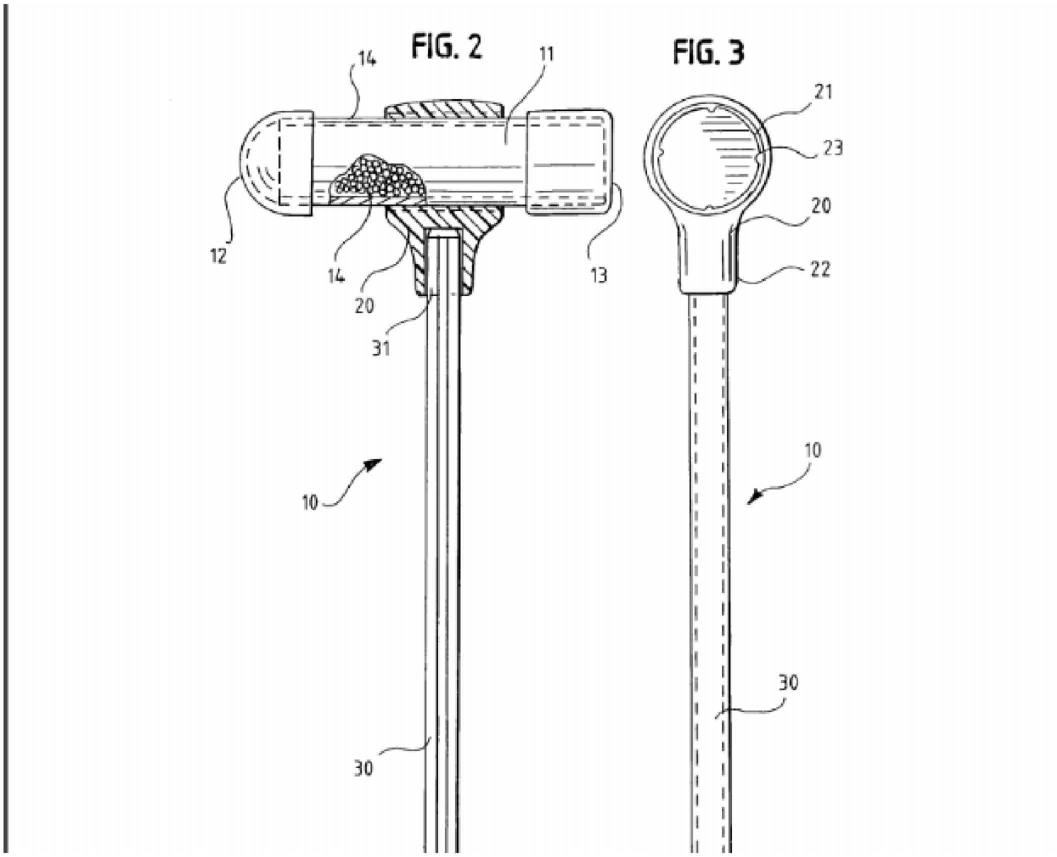
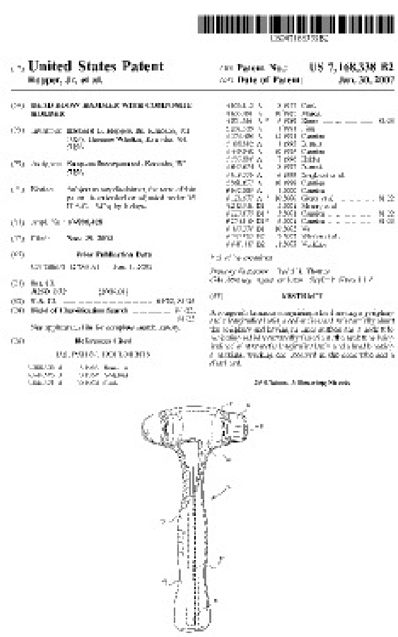



Figure 2: This image takes away the outer shell that is displayed in Figure 1. This image shows the inner pellets that lie inside of the hammer head allowing for the inertia to be limited.

**Conclusions/action items:**

The main aspects that I took away from this patent were the outer grip and whether or not this could affect sterilization if used in our case and the circular tip might allow for a longer life span for the hammer.

WILLIAM BROWN - Sep 21, 2021, 10:01 AM CDT


United States Patent
Hopper, Jr. et al.
US 7,168,338 B2
Jan. 30, 2007

**US7168338.pdf(434.4 KB) - download**

# 9/23/21 Design Idea One

WILLIAM BROWN - Sep 23, 2021, 11:31 AM CDT

**Title: Closed Casing Model**

**Date:** 9/23/21

**Content by:** William Brown

**Present:** William Brown

**Goals:** To show the sketch of my first design idea.

**Content:** The initial design shows a low inertia hammer that has a hollow head but a capsule that fits into the hollow head. This capsule is filled with pellets which provide the majority of the force that stops the blowback after sticking with the hammer. The tip of the hammer can then be screwed into the head of the hammer. The major aspects of this design are the fact that the inter pellet capsule and screw in the head can both be replaced if damaged or broken. I got my ideas partially from one of Connors's drawings which he showed us in our team meeting and also the patent that I researched. I added grip to the handle but this might need to be removed if it is not compatible with sterilization.

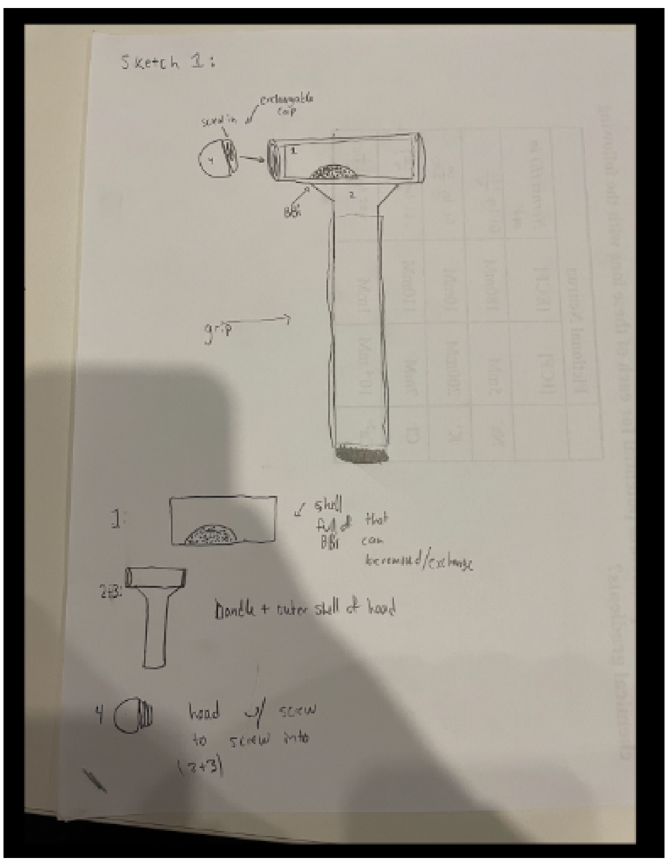
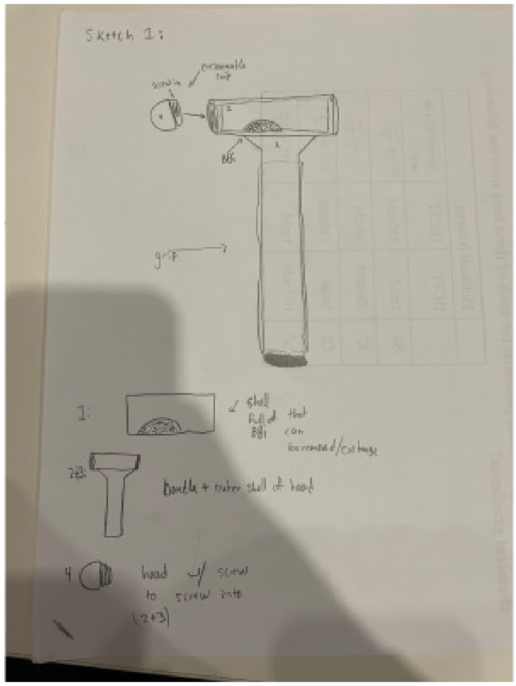



Figure 1: Sketch of my initial design idea. The image shows 4 images. 1: the total combined hammer with a screw in head and complete body. 2: is labeled 1 and shows a capsule of pellets that will slide into the hollow head of the hammer. 3: which is labeled 2+3 in the image shows the hollow head and the handle that is connected. 4: is the tip of the hammer that screws into the head and the handle.

**Conclusions/action items:**

This will be an idea that is brought to the team and determined if we want to continue working on it or want it to stay an idea.

WILLIAM BROWN - Sep 23, 2021, 11:09 AM CDT

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WILLIAM BROWN - Dec 15, 2021, 9:36 AM CST

This was an interesting semester, as the team stuck to our main design throughout the process. The only change was with the threads and slight dimension changes after meeting with the team lab. I would have had more design iterations if there was a need.

# Communication with Brittany Glaeser of BME 315

WILLIAM BROWN - Dec 02, 2021, 11:36 AM CST

**Title: Talking with TA about Using Team Lab**

**Date:** 12/1/21

**Content by:** William Brown

**Present:** ME

**Goals:** To discuss details on what is needed in order to utilize team lab for testing

**Content:**

Brittany and I talked about our project and whether or not using a stainless steel hammer on one of the team labs would be feasible. She mentioned that there is plenty that the team lab at ECB could do but that it would have to be done during either of BME 315s instructors' office hours or if any of the instructors are willing to come in during their free time. This is due to the fact that the team labs facilities have technology that needs to be operated by one of the instructors. Below is an attached image of the office hour sections that could be utilized.

Co-Instructor: Dr. Christa Wille
Email: cmwille@wisc.edu
Responsibilities: Course logistics, Instruction of Module 1 & 2 (Biostatics and Biodynamics)

Co-Instructor: Dr. Stephanie Cone
Email: sgcone@wisc.edu
Responsibilities: Instruction of Module 3 (Tissue Mechanics)

Instructor Office Hours:
Tuesdays, 12-1p
Modality/Location TBD

Additional office hours with instructors are available upon request.

## TA Availability and Preferred Contact :

Elizabeth Schmida (schmida@wisc.edu)
Office Hour: Monday, 1-2p; Location TBD
Lab Section Responsibilities:
TBD

Brittany Glaeser (bmglaeser@wisc.edu)
Office Hour: Thurs 12-1p, Location TBD
Lab Section Responsibilities:
TBD

Figure 1: Part of BME 315 syllabus with office hour times.

To continue, Brittany mentioned that we would need a complete testing protocol with force applied or forces looking to exert before we could begin using the team lab.

**Conclusions/action items:**

This was nice to talk to someone with more experience with the team lab and to learn more about what is needed to be completed. Finding a testing procedure is the next plan.

# 12/8/21 Testing Videos

WILLIAM BROWN - Dec 15, 2021, 9:16 AM CST

**Title: Lab Archives testing Videos**

**Date:** 12/8/21

**Content by:** William Brown

**Present:** Team

**Goals:** Upload testing videos.

**Content:**

Not all the videos are supplied here, some where to large to attach, but all of these videos were taken during the testing in the team lab following the procedure below.

**Dead-Blow Hammer Force Testing Protocol:**

**Materials Needed:**

- Dead blow mallet with steel beads (test)
- Regular mallet w/o dead blow media (control)
- Force plate
- Ruler

**Procedure:**

1. Assemble the dead blow mallet by placing the steel beads in the open space. Seal the end caps of both the dead blow mallet and the control mallet.
2. Set up a ruler for consistent striking. The mallet will be brought up to 0.3 meters (1 foot) before each strike.
3. Prepare the force plate for data collection. Ensure that the force reads zero when no loads are applied.
4. Begin data collection on (Bertec Force plate).
5. Strike the surface of the force plate with the control mallet three consecutive times without stopping in between. Ensure that the mallet is brought back up to the height of the ruler before every strike.
6. Stop data collection.
7. Repeat steps 3-6 for a total of five separate times. Attempt to keep the striking force consistent with each test. This should be at approximately 10% of maximum striking force (for a force of approximately 3-4 kN).
8. Repeat steps 3-7 with the dead blow mallet.
9. Collect all tests and analyze in Matlab

**Notes:**

- A total of 10 tests will be performed with 3 strikes each.
- This should not take more than 15 minutes once all items are prepared
- The striking force will be below 4 kN as the mallets in this test are PLA plastic prototypes
  - The goal is to keep the strikes consistent. One individual will perform all the tests.

**Conclusions/action items:**

Will will likely use a different sort of image capture to test angles of deflection next semester.

WILLIAM BROWN - Dec 15, 2021, 9:13 AM CST

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WILLIAM BROWN - Dec 15, 2021, 9:13 AM CST

**IMG_2784.MOV(24.1 MB) - download**

WILLIAM BROWN - Dec 15, 2021, 9:13 AM CST

**IMG_2783.MOV(37.4 MB) - download**

WILLIAM BROWN - Dec 15, 2021, 9:13 AM CST

**IMG_2782.MOV(26.6 MB) - download**

WILLIAM BROWN - Dec 15, 2021, 9:14 AM CST

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WILLIAM BROWN - Dec 15, 2021, 9:14 AM CST

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WILLIAM BROWN - Dec 15, 2021, 9:14 AM CST

**IMG_2774.MOV(5.4 MB) - download**

WILLIAM BROWN - Dec 15, 2021, 9:14 AM CST

**IMG_2773.MOV(11.4 MB) - download**

# 2021/09/20 - Knee Replacement Research

SAMUEL FERRIS - Oct 19, 2021, 5:34 PM CDT

**Title: Knee Replacement Research**

**Date:** 9/20/2021

**Content by:** Sam Ferris

**Present:** -

**Goals:** Look into total knee replacement surgeries to get a better understanding of what the mallet will be used for

**Content: Link to the website: https://orthoinfo.aaos.org/en/treatment/total-knee-replacement**

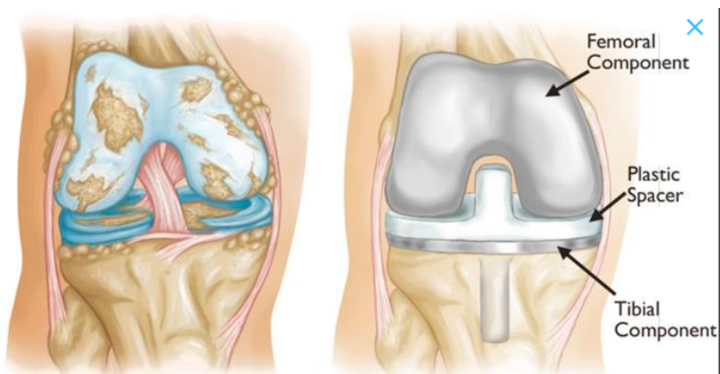
The surgeries that our group intends this mallet to be used for are total knee replacements. I thought it would be a good idea to look into what all goes into these surgeries and why a new mallet would be so beneficial to orthopedic surgeons.

Total knee replacements typically take 1-2 hours from start to finish. These surgeries may be needed for a variety of reasons including arthritis (rheumatoid and osteoarthritis) or from arthritis as a result of a traumatic injury to the bones around the joint.

According to the website, there are four steps to the knee replacement procedure:

1. Prepare the bone - this is where the mallet will be used in conjunction with other surgical instruments to remove damaged cartilage at the ends of both the femur and the tibia. MALLET USED
2. Position the metal implants - this removed cartilage is replaced by metal components to recreate the surface of the joint (cement is typically used to hold in place) MALLET USED
3. Resurface the patella - This is optional (plastic piece added to the patella in a similar fashion as the metal components added to the ends of the femur and tibia) MALLET USED
4. Insert a spacer - plastic medical-grade spacer is inserted between the two metal components on tibia and femur to create smooth gliding surface. MALLET USED

Here is an image of the before and after of this procedure:




**(Left)** Severe osteoarthritis. **(Right)** The arthritic cartilage and underlying bone has been removed and resurfaced with metal implants on the femur and tibia. A plastic spacer has been placed in between the implants. The patellar component is not shown for clarity.

**Conclusions/action items: The total knee replacement process in understood at a basic level (I'm sure it is more complicated depending on the severity of arthritis) . Large amount of patient to patient variability is taken into account. This could result in different size mallets used for different situations that arise depending on patient size, severity of arthritis, patient age, etc.**

# 2021/09/20 - Knee Replacement Research 2

SAMUEL FERRIS - Oct 19, 2021, 5:29 PM CDT

**Title: Knee Replacement Research 2**

**Date:** 9/20/21

**Content by:** Sam Ferris

**Present:** -

**Goals:** Advance my understanding on this procedure

**Content: Link to website:** https://www.healthline.com/health/total-knee-replacement-surgery-step-by-step

This article walks through the step-by-step procedure very clearly. This will be important to include in preliminary report background.

**Conclusions/action items: Come back to this article when writing preliminary report.**

# 2021/09/30 - Autoclave process

SAMUEL FERRIS - Oct 19, 2021, 5:33 PM CDT

**Title: Autoclave process research**

**Date:** 9/30/21

**Content by:** Sam Ferris

**Present:** -

**Goals:** Complete research on the autoclave conditions that our device must be able to withstand.

**Content: Link to website:** https://ehs.princeton.edu/book/export/html/380

The article goes into great detail on the process as a whole. The main numbers that our group is interested in is the duration, temperature, and pressure associated with an autoclave session,

The temperature that it must withstand: 121 degrees Celsius

The pressure it must withstand: 15 psi

For how long (duration of a session): 30 minutes

**Conclusions/action items: These three conditions must be able to be withstood by our hammer prototype that is designed.**

# 2021/10/25 - Grip ergonomics

SAMUEL FERRIS - Dec 04, 2021, 4:45 PM CST

**Title: Grip Ergonomics**

**Date:** 10/25/2021

**Content by:** Sam Ferris

**Present:** -

**Goals:** Find articles relating to grip ergonomics that can be implemented into our design

**Content:**

Article:

https://www.researchgate.net/publication/327228163_Ergonomic_design_of_hammer_handle_to_reduce_musculoskeletal_disorders_of_carpenters

This article researched the best grip dimensions that can be used for normal hammers. The purpose of the article was because a large portion of carpenters in Bangladesh were experiencing wrist pain. Although this article is researching the dimensions for grips on hammers used in carpentry, I believe that the found dimensions can be implemented into our design for the orthopedic mallet.

The following table and image is shown in the article with the dimensions that the article believes to be optimal:

**Table 5:** Proposed dimensions

| Features | Dimensions (cm) | Used Equations |
|---|---|---|
| Optimal grip diameter | 3.368 | [1] |
| Power grip diameter | 3.739 | [2] |
| Grip size | 11.747 | [3] |

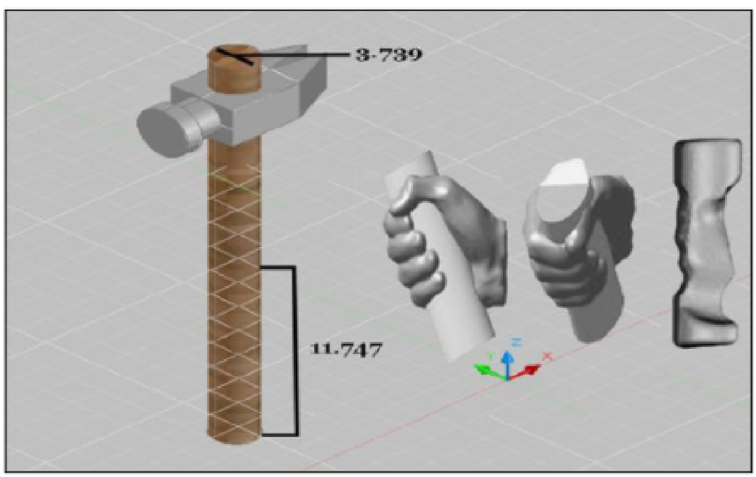



**Fig 8:** CAD design of newly designed hammer

These dimensions might be difficult to implement into our design because the overall model is much smaller than that of a typical hammer used in carpentry. It might be possible to not adjust the whole shaft, but instead just the diameter of the grip portion.

**Conclusions/action items: Bring these dimensions to the group and possibly adjust the dimensions of the grip that our group currently has for our model.**

# 2021/11/25 - Biomechanics of Hammer Swing

SAMUEL FERRIS - Dec 15, 2021, 10:35 AM CST

**Title: Biomechanics of Hammer Swing**

**Date:** 11/25

**Content by:** Sam Ferris

**Present:** -

**Goals:** Define the muscles that are used in swinging a hammer

**Content: Link to website:** https://www.innerbody.com/anatomy/muscular/upper-torso

It is beneficial to understand which muscles are used when the surgeon is actually swinging the mallet.

- The deltoid and supraspinatus muscles run superiorly between the humerus and scapula, allowing abduction, flexion, and extension of the arm.
- These muscles allow for the surgeon to raise his/her arm.
- Rotation of the humerus is caused by the rotator muscles: the subscapularis, infraspinatus, and teres minor. These muscles run from the scapula to the humerus.
- The rotator muscles and the supraspinatus muscle end in tendons that surround the humerus head to form a structure called the rotator cuff.
- In addition to preventing dislocation, the rotator cuff also enables rotation of the humerus.
- This is what is in use when throwing a ball overhand or swinging a hammer/mallet

**Conclusions/action items:**

The rotator cuff is the group of muscles that is under the most physcial activity while a surgeon is swinging an orthopedic mallet.

# 2021/09/16 - CN106691520A Bone Hammer for Orthopedic Surgery

SAMUEL FERRIS - Sep 20, 2021, 3:06 PM CDT

**Title:** CN106691520A Bone Hammer for Orthopedic Surgery

**Date:** 9/16/21

**Content by:** Sam Ferris

**Present:** -

**Goals:** Find existing devices that are currently being used to solve the same issue that we are attempting to solve

**Content:**

杨阳 , "Bone Hammer for Orthopedic Surgery," China Patent 106691520, May 24, 2017.

A Chinese patent was found titled "Bone Hammer for Orthopedic Surgery". The patent was machine translated into English from Chinese, so the sentences do not flow all too well.

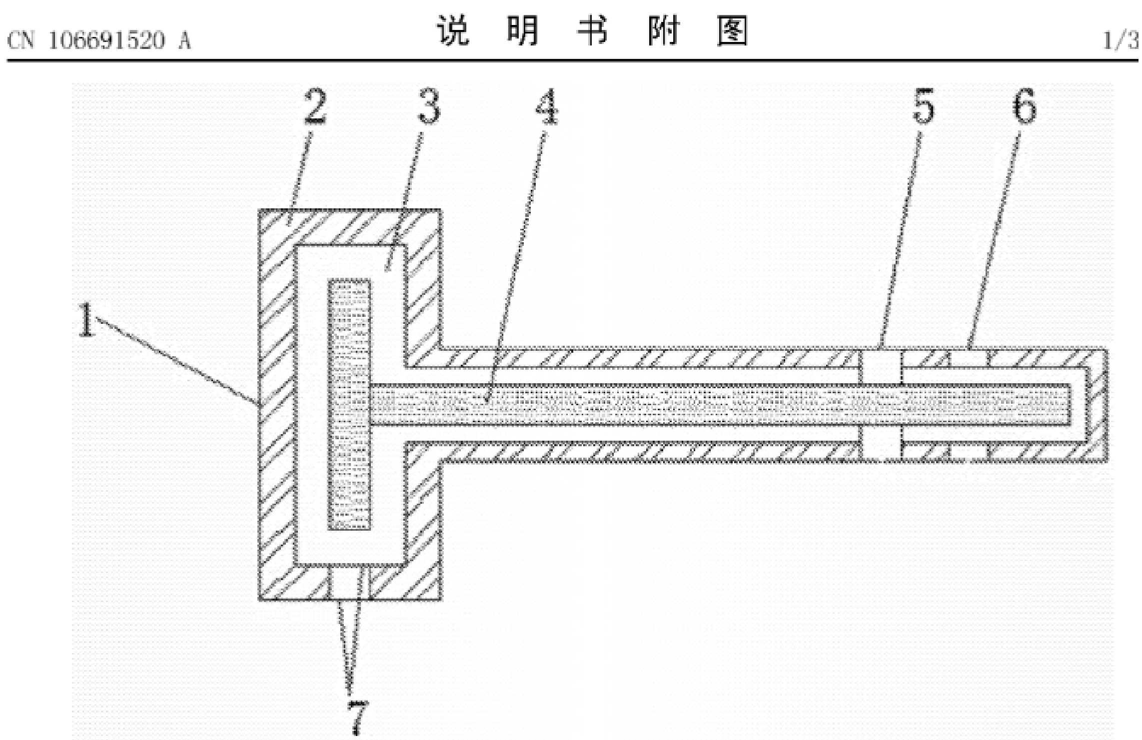



图1

The translation of the patent makes it very difficult to know what exactly the purpose of multiple layers is with this hammer design. The patent may or may not be very useful to look at when we are making our design for the hammer. Can always come back to it later in the semester to possibly understand what is all written in the patent and patent claims.

**Conclusions/action items:** Patent looks like it is relevant to what we are looking to design, but it is difficult to say for sure because of the translation between chinese and english.

SAMUEL FERRIS - Sep 20, 2021, 3:07 PM CDT

# 2021/09/16 - CN211934193U Novel Bone Hammer for Orthopedic Surgery

SAMUEL FERRIS - Sep 20, 2021, 3:04 PM CDT

**Title:** CN211934193U Novel Bone Hammer for Orthopedic Surgery

**Date:** 9/16/21

**Content by:** Sam Ferris

**Present:** -

**Goals:** Find existing devices that are currently being used to solve the same issue that we are attempting to solve

**Content:**

李海涛, "Novel Bone Hammer for Orthopedic Surgery," China Patent 211934193, Nov. 17, 2020.

Just like the previous patent (CN106691520A), this patent is also translated from Chinese to English. However, this patent reads much better with its translation than the other patent.

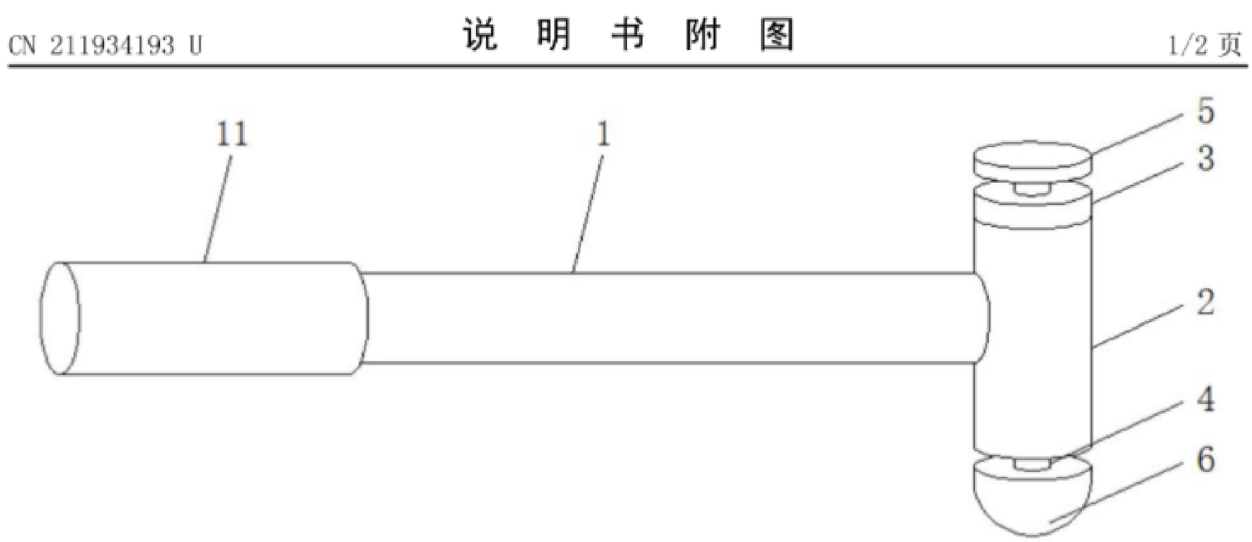



图1

Above is drawing 1 on the associated patent. It gives a visual of one of the embodiments of the patent that is described. According to the patent claims, the cap of the hammer is screwed into the rod and is therefore replaceable after a certain amount of uses. This would add to the long-term durability of the product. Whenever the head of the hammer would wear out to a certain degree, it can be replaced to extend its long-term life. However, this would add the issue of the possibility that the cap were to unscrew when striking during surgery leading to a mess during surgery. Also, the fact that it is removeable, allows different sized and weighted hammer heads to be connected to the hammer rod. This would be useful if different parts of a surgery required different sized hammer heads.

Also, the patent claims speak of a hollow inside of the hammer head. Inside this hollow head is a spring. I am not exactly sure what the purpose of the spring is because of the translation from chinese to english. However, this is very interesting as I would think it would alter the force that is being applied by the surgeon while using the hammer.

**Conclusions/action items:** Make note of this patent and share with team about the different features associated with the patent.

# 2021/09/18 - Typical orthopedic Mallet

SAMUEL FERRIS - Oct 19, 2021, 5:02 PM CDT

**Title: Typical Orthopedic Mallet**

**Date:** 9/18/2021

**Content by:** Sam Ferris

**Present:** -

**Goals:** Find what a typical orthopedic mallet that is currently being used looks like and get some specifications on it.

**Content: Link for this mallet: http://novosurgical.com/orthopedic-mallet-26257.html**

A mallet found on the website of Novosurgical was found. The mallet is made entirely of stainless steel. The mallet is priced at $90 + shipping, and varies on the size.

There are two options for sizing: 1 pound with a 1.5" head in diameter, or 3 pounds with 1.875" head in diameter.

- Keep this in consideration when thinking of sizes for our mallet.
- Probably can be anywhere in this range of 1-3 pounds (about 4-12 N) and have roughly the same head diameter
    - Might be interesting to test if changing the hammer head width would change for exerted, or if that would not be beneficial to the design.

Here is the image from the website:


**Conclusions/action items:** Common orthopedic mallet dimension were found as well as a visual for what the current state of art looks like.

# 2021/10/22- Ergonomics Research, Grip

**Title:** Ergonomic design of hammer handle

**Date:** 10/22/2021

**Content by:** Connor Link

**Goals:** Research the optimal dimensions for the use of hammers

**Source:** [1] T. Haque. "Ergonomic design of hammer handle to reduce musculoskeletal disorders of carpenters," *International Journal of Research in Advai* 4, no. 2. 2018. [Online]. Available at: <https://www.researchgate.net/publication/327228163_Ergonomic_design_of_hammer_handle_to_reduce_musculoskeletal_disorders_of_carpenters/link/5 (Accessed 22 Oct. 2021).

**Content:**

Purpose/Goal:

The goal of this paper was to investigate the dimensions of handles for different mallets/hammers used in the construction industry. These dimensions were "economic discomforts and injuries" through use of the hammer [1].

Although this paper investigated hammers used in carpentry, it is our belief that this will translate similarly to orthopedic mallets as it is largely the same mot should be completed to ensure this is true.

Motivation:

This study also investigated different musculoskeletal effects due to the use of mallets in carpenters through a survey of 300 individuals, with an average ag 11.7. The table that they provided is presented in Table 1. The carpenters were all residents of Bangledesh.

*Table 1: 300 carpenters responded to a survey and the results are seen in this table. The major effect was wrist pain and should be taken into further consi*

| Musculoskeletal Disorders | No. of Workers | Percentage of Workers (%) |
|---|---|---|
| Headache | 150 | 50 |
| Shoulder pain | 195 | 65 |
| Wrist pain | 260 | 87 |
| Stiffness in finger | 215 | 72 |
| Soreness in elbow | 183 | 61 |

Results:

Through the use of anthropometric data, the researchers found that the optimal cylindrical diameter should be approximately 3.368 cm and the grip length s survey they found that discomforts were limited at this size (for example wrist pain prevalence decreased from 87% to 72% of respondents).

**Conclusions/action items:**

These provided dimensions will offer a starting point for the handle dimensions that we will use for our first iteration of design. Those were as follows:

- Diameter -- 3.4 cm
- Length -- 11.7 cm (at a minimum)

# 2021/09/17-Current Orthopedic Mallet

CONNOR LINK - Sep 17, 2021, 11:36 AM CDT

**Title:** Currently used Orthopedic Mallet (as discussed from Client)

**Date:** 9/17/2021

**Content by:** Connor Link

**Goals:** Review the orthopedic mallet that the client sent over for specs/features

**Content:**

The client forwarded a link of an orthopedic mallet for perspective of the tools used. The website does not contain a lot of information but certain specs are available.

*Figure 1: OrthoMed orthopedic mallet, heavyweight with a short handle.*

The outlines specs were as follows:

- Length (Height) - 191 mm (7.5")
- Material - Solid Stainless Steel
- Weight (Overall) - 900 g
- Weight (Head) - 600 g
- Head Diameter - 38 mm

Although I would have liked to have a few more specifications or a dimensional drawing. This gives a good starting point for what is used in the clinical setting. I am most interested in the material here. We should look into fabrication possibilities at UW with stainless steel.

**Conclusions/action items:**

The OrthoMed orthopedic mallet is the mallet provided by the client for reference. Further research should be done into the specs of other orthopedic mallets, but this is a good target for design.

We should look into the possibility of manufacturing a prototype with stainless steel.

# 2021/09/17- Low Inertia Hammer

CONNOR LINK - Sep 18, 2021, 2:30 PM CDT

**Title: Low Inertia Medical Hammer for Trauma/Orthopedic Surgery**

**Date:** 9/17/2021

**Content by:** Connor Link

**Goals:** Review an article detailing a low intertia (dead-blow) hammer that was studied in Russia.

**Content:**

**Source:** [1] "Low Inertia Medical Hammer for Trauma and Orthopedic Surgery" (update this to IEEE later).

This article was translated from a Russian journal and details the study of a dead-blow hammer used in orthopedic surgeries. It also has the patent number cited which should be researched more.

Background Information:

- Orthopedic Hammer Classifications by Weight:
    - Minihammers - 113 to 400 g
    - Average Hammers - 400 to 699 g
    - Heavy Hammers - 700+ g
        - These are commonly used in arthroplasty to increase the force.
- Generally an increase in the impact efficiency is solved by increasing the mass, however, this is more strenuous for the surgeon and can lead to errors, fatigue, overshoot, deviation from the desired axis, etc.

The Hammer

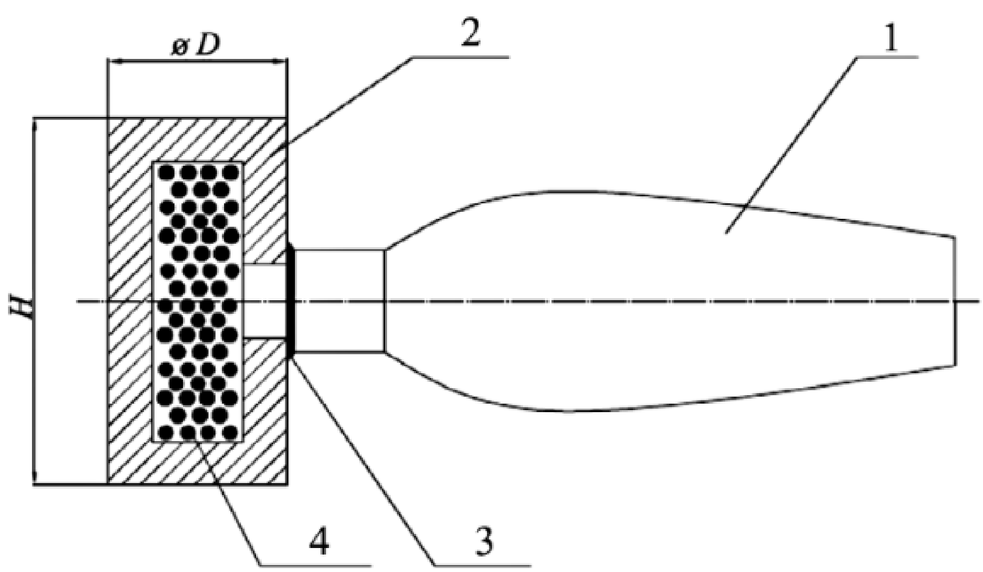



*Figure 1: The low-inertia impact hammer studied in the paper [1]. This resembles a dead blow hammer.*

Some specifications detailed (look into the patent for further information):

- Total weight was 630 g
  - 45 grams of this were the steel balls
  - Handle was 220 g
  - Head was 365 g (w/o the balls)
- The handle was secured by welding
- The paper states "downsizing the hammer weight takes it to the class of average hammers, while its impact efficiency corresponds to the class of heavy hammers." However, a statistical analysis of this is not detailed in the paper.

Methods/Results

The methods detailed in this study are to determine the characteristics of the hammer strike. These included: time of impact interaction and rebound length between the Low-Inertia Hammer and a Standard Hammer.

- A high-speed video was used using FastVideo-250 highspeed digital video camera
  - Recording was 1500 frames/sec
- The surgeon struck 3 times with either hammer and a ruler was placed next to the hammer to determine rebound

The results were presented in a table. No statistical analyses were performed, however.

| Impact number | Low-inertia hammer | | Standard hammer | |
|---|---|---|---|---|
| | Time of impact interaction, s | Rebound, mm | Time of impact interaction, s | Rebound, mm |
| 1 | 0.045 | 0 | 0.003 | 3 |
| 2 | 0.084 | 0 | 0.008 | 3 |
| 3 | 0.18 | 0 | 0.02 | 3 |

*Table 1: Results for the study between the low-inertia hammer and a standard hammer.*

As Table 1 details, the time of impact of the dead blow hammer was nearly 9-17x greater than that of the standard hammer. Also (in this crude measurement system), there was no rebound of the dead blow hammer.

The paper also suggests "that during the impact the standard hammer deviates from the axis of impact, which leads to incorrect distribution of the impact vector, unwanted bone injury, loss of impact energy, and, correspondingly, decreased impact efficiency."

- This however is not backed up with any data other than a picture that is fairly unclear.

Conclusions

The authors suggest that the dead blow hammer proposed "increases the impact alignment of the vector, improving the impact efficiency". However, further studies with a much larger sample size should be completed before saying these results with confidence.

**Conclusions/action items:**

Conclusions

This study suggests promise in the efficacy of a dead blow hammer in orthopedic surgeries. However, there is minimal data and minimal evidence provided to support the conclusions of the authors. Further studies (with more numbers of blows from a variety of people or a standard device) should be conducted before believing these conclusions.

Action Items

The article contains a patent number for the low-impact (dead blow) hammer that was studied. Upon initial searching, it was difficult to find, but I will continue to look.

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CONNOR LINK - Sep 17, 2021, 12:32 PM CDT

DOI 10.1007/s10527-015-9499-5
Biomedical Engineering, Vol. 49, No. 2, July, 2015, pp. 67-70. Translated from Meditsinskaya Tekhnika, Vol. 49, No. 2, Mar.-Apr., 2015, pp. 4-6. Original article submitted June 5, 2014.

**Low-Inertia Medical Hammer for Trauma and Orthopedic Surgery**

**G. M. Kavalersky[1*], E. I. Semenov[2], A. P. Sereda[1], A. V. Lychagin[1], V. Yu. Lavrinenko[1], and A. S. Ayrapetyan[2]**

*The results of an experimental study of endoprosthetic operations of knee and hip joints with the low-inertia Kavalersky–Semenov medical hammer are presented. The hammer has increased time of interaction between the main part of the hammer and the struck surface of the rasp; there is no rebound compared to a standard hammer, which increases the efficiency of the impact, facilitates the work of the surgeon with the hammer, and reduces the risk of injury.*

**Introduction**

Many trauma and orthopedic surgeries require the surgeon to use a medical hammer for manipulating bone (osteotomy, osteoclasis, osteoperforation, processing intramedullary canal with rasp, etc.) and for the introduction of implants (installation of joint components, introduction of intramedullary pins).

On one hand, the medical hammer must ensure maximum efficiency of the impact, and on the other, the use of the hammer should be safe for both the patient and the surgeon. Therefore, manufactured hammers have requirements of ergonomics to provide convenient operation for the surgeon: the hammer must be balanced by the mass of the performed manipulation, have a comfortable non-slip handle, not vibrate during rebound after impact, and be strong enough to ensure no mechanical destruction of the hammer, especially in the junction between the hammer head and handle.

All existing hammers differ in just these ergonomic parameters. Minihammers and lightweight hammers have weights from 113 to 400 g (hammers Lucas, Hajek, Partsch, Cottle, Collin, Gerzog, Cloward, Crane, etc.). The heads of these hammers are made of steel but can have a lead core; sometimes the striking surface has a nylon cover. The handle can be made of steel or polymeric plastics. There are lightweight hammers made entirely of plastics.

Average hammers have mass greater than 400 g (Bergman and Kirk hammers), the striking part may be heavily weighted (filled with lead) or lightly weighted (e.g. the Kirk hammer is filled with brass). The ergonomic handle of these hammers can be of either metal or plastic.

Heavy hammers have a weight greater than 700 g (hammers Ombredanne, Heath, He-Man, etc.), and these hammers are used by surgeons most often when performing arthroplasty, because the processing of the intramedullary canal using a rasp to the shape of the implant requires considerable physical effort.

The issue of increasing the impact efficiency in this case is solved by a simple increase in hammer mass, but an increase in hammer mass leads to physical fatigue of the surgeon and thus increase in the number of errors. In particular, when using a heavy hammer, a surgeon can not only overshoot, but also deviate from the desired axis, which can lead to injury. To minimize the risk of error of the surgeon, in 1927 Horace C. Pitkin suggested using a special pneumatic hammer [1], with obvious disadvantages being high price and unreliability.

[1] Sechenov First Moscow State Medical University, Moscow, Russia; E-mail: [illegible]
[2] Moscow State Industrial University, Moscow, Russia.
* To whom correspondence should be addressed.

67

[illegible]

**Kavalersky2015_Article_Low-InertiaMedicalHammerForTra.pdf(465.1 KB) - download**

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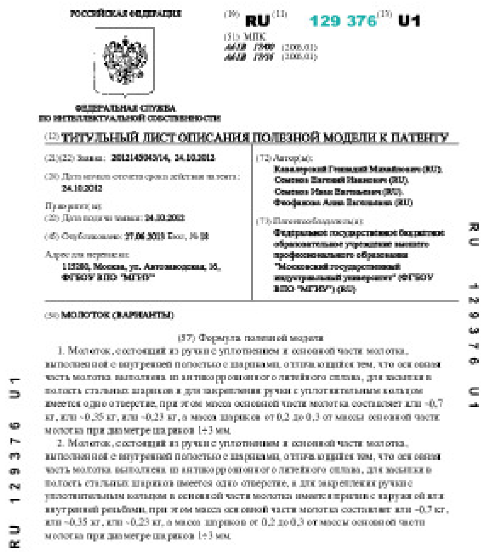
CONNOR LINK - Sep 17, 2021, 4:08 PM CDT

The patent is for the device described above is attached below here. It is a Russian patent (RU) and has status IP Right Cessation

CONNOR LINK - Sep 17, 2021, 4:04 PM CDT



РОССИЙСКАЯ ФЕДЕРАЦИЯ

ФЕДЕРАЛЬНАЯ СЛУЖБА ПО ИНТЕЛЛЕКТУАЛЬНОЙ СОБСТВЕННОСТИ

(19) RU (11) 129 376 (13) U1

(51) МПК
[illegible] (2006.01)
[illegible] (2006.01)

(12) ТИТУЛЬНЫЙ ЛИСТ ОПИСАНИЯ ПОЛЕЗНОЙ МОДЕЛИ К ПАТЕНТУ

(21)(22) Заявка: 2012145043/14, 24.10.2012

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(54) МОЛОТОК (ВАРИАНТЫ)

(57) Формула полезной модели

1. Молоток, состоящий из ручки с уплотнением и основной части молотка, выполненной с внутренней полостью с шариками, отличающийся тем, что основная часть молотка выполнена из антикоррозионного литейного сплава, для засыпки в полость стальных шариков и для закрепления ручки с уплотнительным кольцом имеется одно отверстие, при этом масса основной части молотка составляет или ~0,7 кг, или ~0,35 кг, или ~0,23 кг, а масса шариков от 0,2 до 0,3 от массы основной части молотка при диаметре шариков 1÷3 мм.

2. Молоток, состоящий из ручки с уплотнением и основной части молотка, выполненной с внутренней полостью с шариками, отличающийся тем, что основная часть молотка выполнена из антикоррозионного литейного сплава, для засыпки в полость стальных шариков имеется одно отверстие, а для закрепления ручки с уплотнительным кольцом в основной части молотка имеется прилив с наружной или внутренней резьбами, при этом масса основной части молотка составляет или ~0,7 кг, или ~0,35 кг, или ~0,23 кг, а масса шариков от 0,2 до 0,3 от массы основной части молотка при диаметре шариков 1÷3 мм.

**RU129376U1_Russian_Patent_for_Dead_Blow_Hammer.pdf(569.4 KB) - download** This attachment is the Russian patent (RU) for the hammer described in this article.

# 2021/09/18-Dead blow hammer head (EXPIRED)

CONNOR LINK - Sep 18, 2021, 2:13 PM CDT

**Title: Patent for dead blow hammer head**

**Date:** 9/18/2021

**Content by:** Connor Link

**Goals:** Review the patent for the first dead blow hammer head (1965; now expired)

**Found At:** [https://patents.google.com/patent/US3343576A/en?q=dead+blow+hammer&oq=dead+blow+hammer](https://patents.google.com/patent/US3343576A/en?q=dead+blow+hammer&oq=dead+blow+hammer)

**Content:** US3343576A, EXPIRED

This is the first found patent for a dead blow hammer head design. It is now currently listed as expired.

Features:

- Described as main use for an industrial setting
- Includes removable ends for replacement when the mallet becomes worn
- Double-sided for striking
- Filled with a material (usually lead or steel balls) that absorbs the impact by shifting within an internal chamber. This prevents recoil.

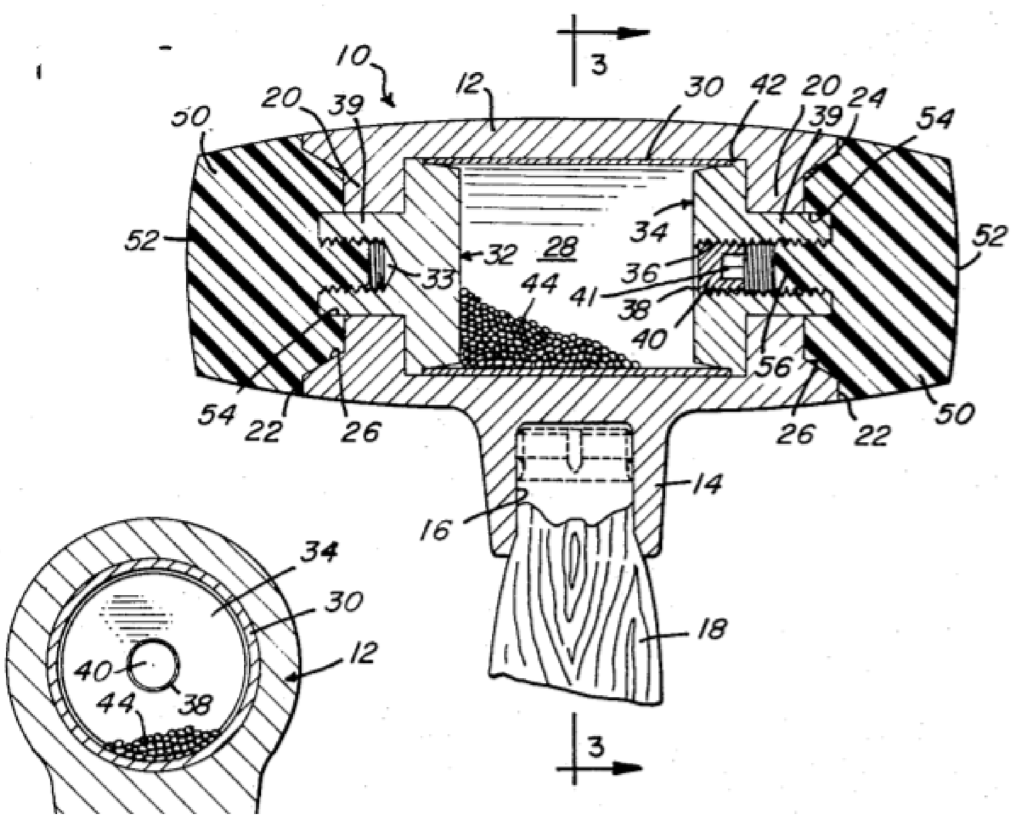
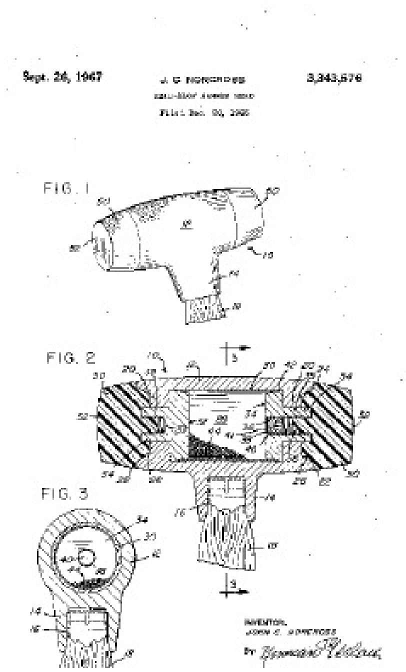


*Figure 1: Image in the patent of interest detailing a dead-blow hammer design for the head of the mallet. Includes removable caps.*

**Conclusions/action items:**

This patent is a good start for dead blow hammers, but further searching should be done for currently held patents (especially relating to the medical industry).

CONNOR LINK - Sep 18, 2021, 2:25 PM CDT




**Expired_US3343576_Dead_Blow_Hammer_Head.pdf(424.9 KB) - download**

# 2021/09/18-Encapsulated Dead Blow Hammer

CONNOR LINK - Sep 18, 2021, 2:13 PM CDT

**Title: Encapsulated dead blow hammer with improved skeleton**

**Date:** 9/18/2021

**Content by:** Connor Link

**Goals:** Look into an active patent for a dead blow hammer design

**Found At:** **https://patents.google.com/patent/US6595087B2/en?q=dead+blow+hammer&oq=dead+blow+hammer**

**Content:** US6595087, ACTIVE

Features

- Keeps the handle from extending through the inner chamber of the head (which may inhibit the flow of the filling).
- Focuses on the structure of the skeleton to better distribute the weight of the hammer. And be economically advantageous.
- The end caps are press fitted (non-removable).

Key Claims

- The hammer is formed with the use of plastic (spacer) and the handle uses fiberglass.
- The hammer is surrounded by a plastic sheath
- Handle is secured to the neck tube with adhesive.
- Press fitted end caps.

Other Notes/Thoughts

- Does not specify the intended use/industry.

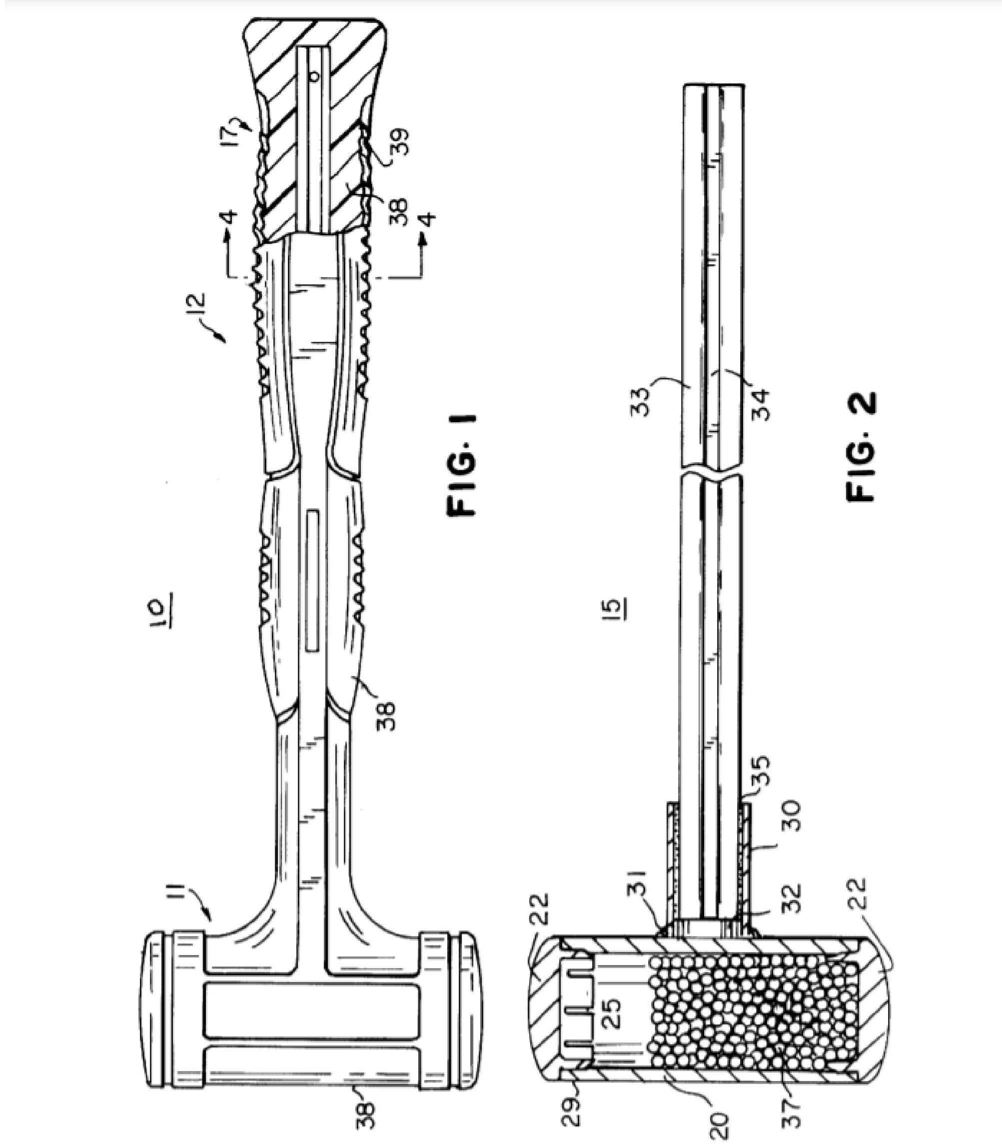
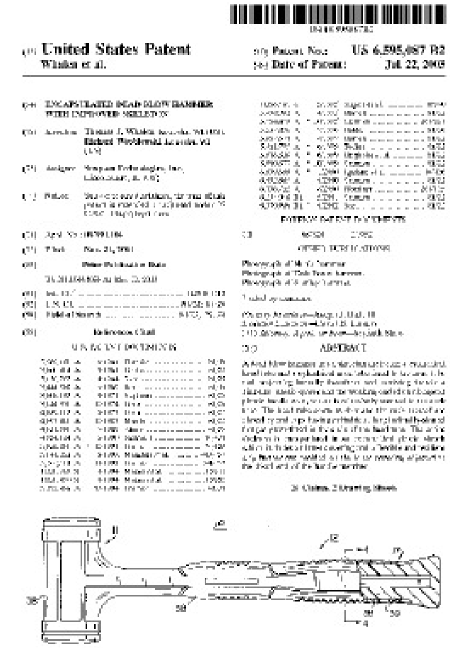



*Figure 1: Drawings of the patent of interest for the design of a Dead-Blow Hammer.*

**Conclusions/action items:**

This is currently an ACTIVE patent in the US. Would need to consult experts/advisors about how this relates to our intended design and if our design is "unique" comparatively.

CONNOR LINK - Sep 18, 2021, 2:26 PM CDT


United States Patent
Whalen et al.
Patent No.: US 6,595,087 B2
Date of Patent: Jul. 22, 2003
ENCAPSULATED DEAD BLOW HAMMER WITH IMPROVED SKELETON
References Cited
U.S. PATENT DOCUMENTS
FOREIGN PATENT DOCUMENTS
OTHER PUBLICATIONS
ABSTRACT

**US6595087_Encapsulated_dead_blow_hammer_with_improved_skeleton.pdf(531.9 KB) - download**

# 2021/09/18-Dead blow hammer with composite holder

CONNOR LINK - Sep 18, 2021, 2:13 PM CDT

**Title: Dead blow hammer with composite holder (2007)**

**Date:** 9/18/2021

**Content by:** Connor Link

**Goals:** Look into an active patent for a dead blow hammer design

**Found At: https://patents.google.com/patent/US7168338B2/en?q=dead+blow+hammer&oq=dead+blow+hammer**

**Content:** US7168338, ACTIVE

Features

- Composite dead blow hammer
- Encapsulated with an outer casing

Key Claims

- The handle is formed from fibrous materials (fiberglass).
- The casing is of an elastomeric material
- Inner ribs (pointed out with label 23 in Figure 1).

Other Notes/Thoughts

- No industry is specified.
- Held by the same company as US6595087, "Snap-On Technologies" Kenosha, WI

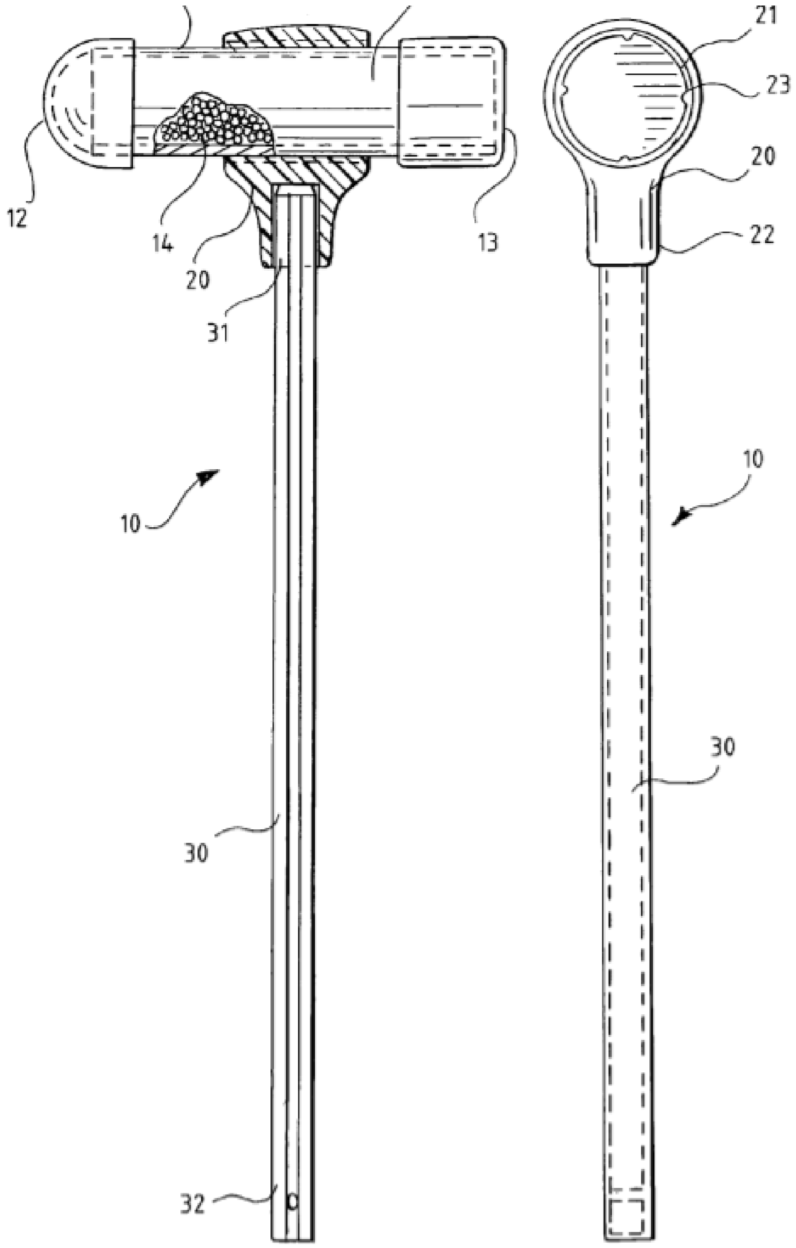
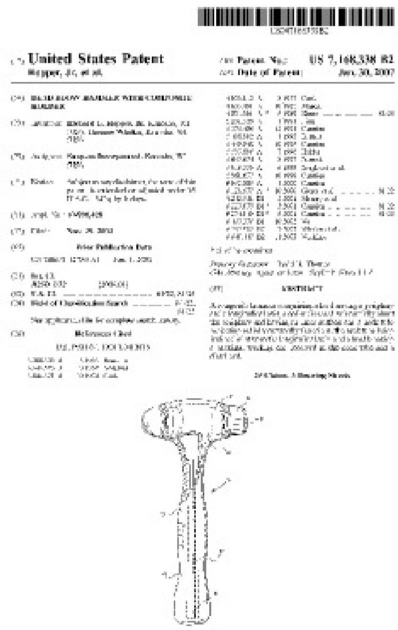



*Figure 1: Drawings of the patent of interest for the design of a Dead-Blow Hammer.*

**Conclusions/action items:**

This is currently an ACTIVE patent in the US. Would need to consult experts/advisors about how this relates to our intended design and if our design is "unique" comparatively.

CONNOR LINK - Sep 18, 2021, 2:26 PM CDT


United States Patent
US 7,168,338 B2
Jan. 30, 2007

**US7168338_Dead_blow_hammer_with_composite_holder.pdf(434.4 KB) - download**

# 2021/09/18-RU Dead blow hammer

CONNOR LINK - Sep 18, 2021, 2:31 PM CDT

**Title: RU Dead blow hammer (described in research).**

**Date:** 9/18/2021

**Content by:** Connor Link

**Goals:** Look into a patent for a dead blow hammer design

**Found At:** [https://patents.google.com/patent/RU129376U1/en?oq=RU129376](https://patents.google.com/patent/RU129376U1/en?oq=RU129376)

**Content:** RU129376U1, IP RIGHT CESSATION

Features

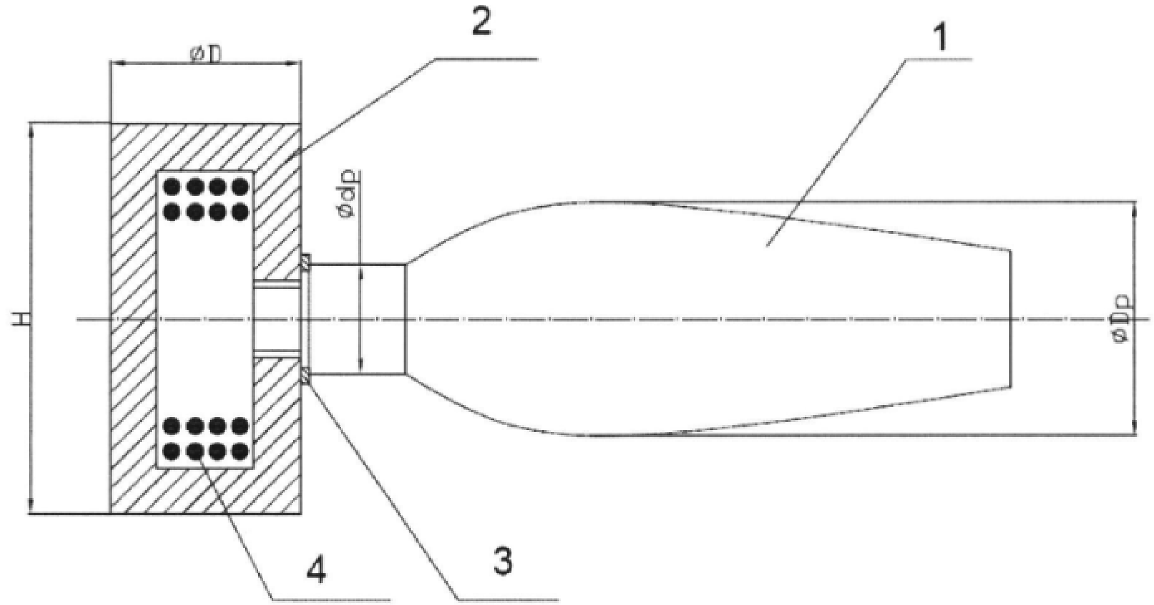
- Main part of the hammer is anti-corrosion cast ally
- Mass is either ~0.7 kg, ~0.35 kg, or ~0.23 kg
- Relates to industrial applications and medical (specifically surgical) operations
- Mass of the balls (steel) is from 0.2 to 0.3 the mass of the main part of the hammer (ball diameter is 1/3 mm)
- Handle is secured with an external or internal thread
- There is a hole in the main part to fill the inner chamber with the balls

Key Claims

- Mass is either ~0.7 kg, ~0.35 kg, or ~0.23 kg
- Mass of the balls (steel) is from 0.2 to 0.3 the mass of the main part of the hammer (ball diameter is 1/3 mm)

Other Notes/Thoughts

- The patent was only filed in Russia (RU) but is NOT currently listed as active.




Фиг.1

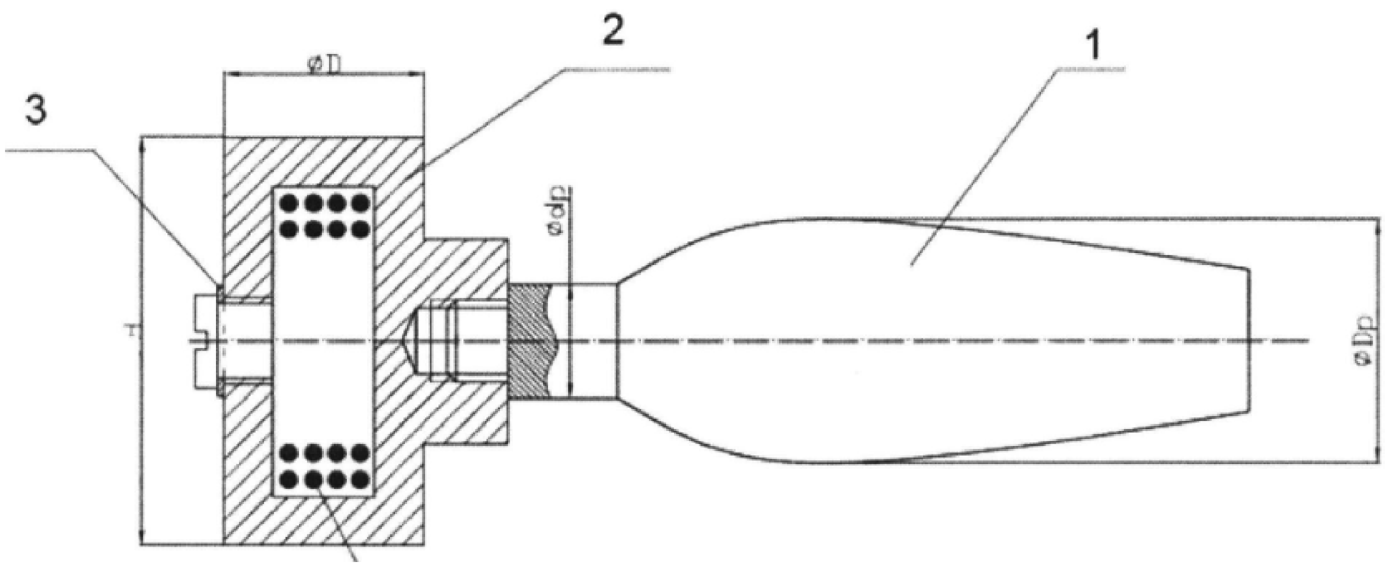



*Figure 1: Drawings of the patent of interest for the design of a Dead-Blow Hammer.*

**Conclusions/action items:**

This is currently NOT an ACTIVE patent in the US, nor has it ever been (according to my research). Would need to consult experts/advisors about how this relates to our intended design especially about the fact it was held in a different country. Also, what does IP Right Cessation mean in terms of status of the patent?

CONNOR LINK - Sep 18, 2021, 2:25 PM CDT

РОССИЙСКАЯ ФЕДЕРАЦИЯ

(19) RU (11) 129 376 (13) U1

(51) МПК
[illegible] (2006.01)
[illegible] (2006.01)

ФЕДЕРАЛЬНАЯ СЛУЖБА
ПО ИНТЕЛЛЕКТУАЛЬНОЙ СОБСТВЕННОСТИ

(12) ТИТУЛЬНЫЙ ЛИСТ ОПИСАНИЯ ПОЛЕЗНОЙ МОДЕЛИ К ПАТЕНТУ

(21)(22) Заявка: 2012145043/14, 24.10.2012

(24) Дата начала отсчета срока действия патента: 24.10.2012

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(45) Опубликовано: 27.06.2013 Бюл. № 18

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(54) МОЛОТОК (ВАРИАНТЫ)

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RU 129376 U1

RU 129376 U1

**RU129376U1_Russian_Patent_for_Dead_Blow_Hammer.pdf(569.4 KB) - download**

# 2021/09/18 - Metallic Biomaterials

CONNOR LINK - Oct 19, 2021, 3:40 PM CDT

**Title: Metal Biomaterials for use in the Dead Blow Hammer**

**Date:** 09/18/2021

**Content by:** Connor Link

**Goals:** Gather information about the different metals used in surgical applications

**Source(s):** [1] K. L. Ong, S. Lovald, and J. Black, "Metals," in *Orthopaedic Biomaterials in Research and Practice, Second Edition.* CRC Press. 2014. pp. 175-178.

[2] "AISI 440 Stainless Steel," *Matweb*, [Online]. Available at: <http://www.matweb.com/search/datasheet.aspx?matguid=704ebd5797b944898f5cf39260fecce0&ckck=1> [Accessed: Sept. 18, 2021].

**Content:**

I first researched different metals used in medical applications by referencing the textbook Orthopaedic Biomaterials in Research and Practice, Second Edition [1]. In the stainless steels section, it suggested that there were two main types of surgical steels, austenitic and martensitic. The austenitic stainless steels were stronger and are designated as AISI 440 Stainless Steel. The martensitic stainless steels have superior corrosion resistance, however, lose some strength/toughness. These are called 316L stainless steels, generally.

I then researched the different material properties of these two steels using Matweb [2]. 440 had a much higher **yield stress at 1280 MPa** than the 316L stainless steels, and thus will be the target of further research for the hammer.

**Conclusions/action items:**

It will be important to find a supplier who can get AISI 440 stainless steel and ensure that the fabricator can work with this material to our specifications.

# 2021/09/23 - Evaluation of Forces, Orthopedic Hammer

CONNOR LINK - Oct 19, 2021, 3:33 PM CDT

**Title:** Evaluation of Striking Forces

**Date:** 09/23/2021

**Content by:** Connor Link

**Goals:** Determine a starting point for the forces that are generated by orthopedic surgeons.

**Source:** G. Schmidig et al. “Evaluation of Variability in Head Impaction Forces Among Multiple Orthopaedic Surgeons.” unpublished. [Online]. Available at: <http://www.ors.org/Transactions/61/1708.pdf> [Accessed 23 Sept. 2021].

**Content:**

This study examined the forces generated by surgeons in a simulated environment for the insertion of a cobalt chrome head onto a titanium stem in a sawbone (fake bone). It used 8 experienced surgeons (for a total of 44 strikes) and attached a 50 kN load washer to the end of the mallet to determine the forces generated.

The study found that the maximum force generated 26,602 N with an average force of 14,855 N.

These values were used to calculate the maximum expected force for the hammer, in order to determine materials and dimensions in the future. The maximum force of 26,602 N was multiplied by a factor of safety of 1.5 to gather a force of 39,903 N.

We will use the value of 40 kN for the determination of forces/stresses moving forward in the design process. This value is only used as a metric for the approximate forces that are generated. Testing of a standard surgical mallet should still be performed in the course of this design process to determine the forces generated by a standard mallet compared to a dead blow mallet.

**Conclusions/action items:**

It is important to note that this value may be higher when striking a flat surface, compared to when the surgeon was required to strike the cobalt head.

# 2021/10/08 - Calculation of Mechanical Properties

CONNOR LINK - Oct 19, 2021, 3:24 PM CDT

**Title:** Calculation of Mechanical Properties for the Dead Blow Hammer

**Date:** 10/08/2021

**Content by:** Connor Link

**Goals:** Determine the dimensions of the hammer that would not lead to failure

**Content:**

After determining the rough yield stress of AISI 440 Stainless Steel (1280 MPa) I ran calculations for the stress on the hammer when compared to different dimensions of interest. I also assumed that the impact force would at most achieve 40 kN from a different study (discussed on the Evaluation of Forces page).

First I calculated the stress on the caps (assuming uniform distribution of stress) for the end caps of the hammer at varying diameters (2.54 cm, 7.62 cm, and 3.80 cm), using the equation stress = force/cross-sectional area. The different sizes were chosen to give a range of values, and the 3.80 cm is from an example mallet that Dr. Wollaeger showed us. This was as follows in Table 1:

*Table 1: Stress calculations for the end caps.*

| Diameter (m) | Area (m^2) | Stress (MPa) |
|---|---|---|
| 0.0254 | 5.065e-4 | 78.94 |
| 0.0762 | 45.58e-4 | 8.77 |
| 0.0380 | 10.18e-4 | 39.30 |

These stresses were all well under the yield stress. A diameter of **40 mm** was chosen to allow for a similar feel to current hammers in use, and also still allow room for the inner casing with the metal beads.

The next calculation was that of the internal diameter. I calculated this using a set outer diameter of 40 mm. This was calculated by substracting the area of the outer diameter by the area of the inner diameter, then calculating the stress as above. An inner diameter of 30 mm was settled on which would result in 72.76 MPa, which is well under the 1280 MPa yield stress.

The final calculation was done to determine the feasibility of the diameter for the handle. The starting point was to use the diameter of a standard surgical mallet which was about 18.3 mm. The shear stress calculated for this diameter would be 153 MPa which is well under the yield as well.

**Conclusions/action items:**

The overall dimensions are:

Outer Diameter = 40 mm

Inner Diameter = 30 mm

Handle Diameter = 18.3 mm

These measurements will be used for the preliminary design in Solidworks.

# 2021/11/10-Volume Calculations

CONNOR LINK - Dec 14, 2021, 2:02 PM CST

**Title: Calculations for the bead volumes in the inner chamber of the mallet**

**Date:** 11/10/2021

**Content by:** Connor Link

**Goals:** Determine the number of beads necessary for the appropriate filling of beads

**Content:**

Figure 1 contains the calculations that were used to determine the number of beads.

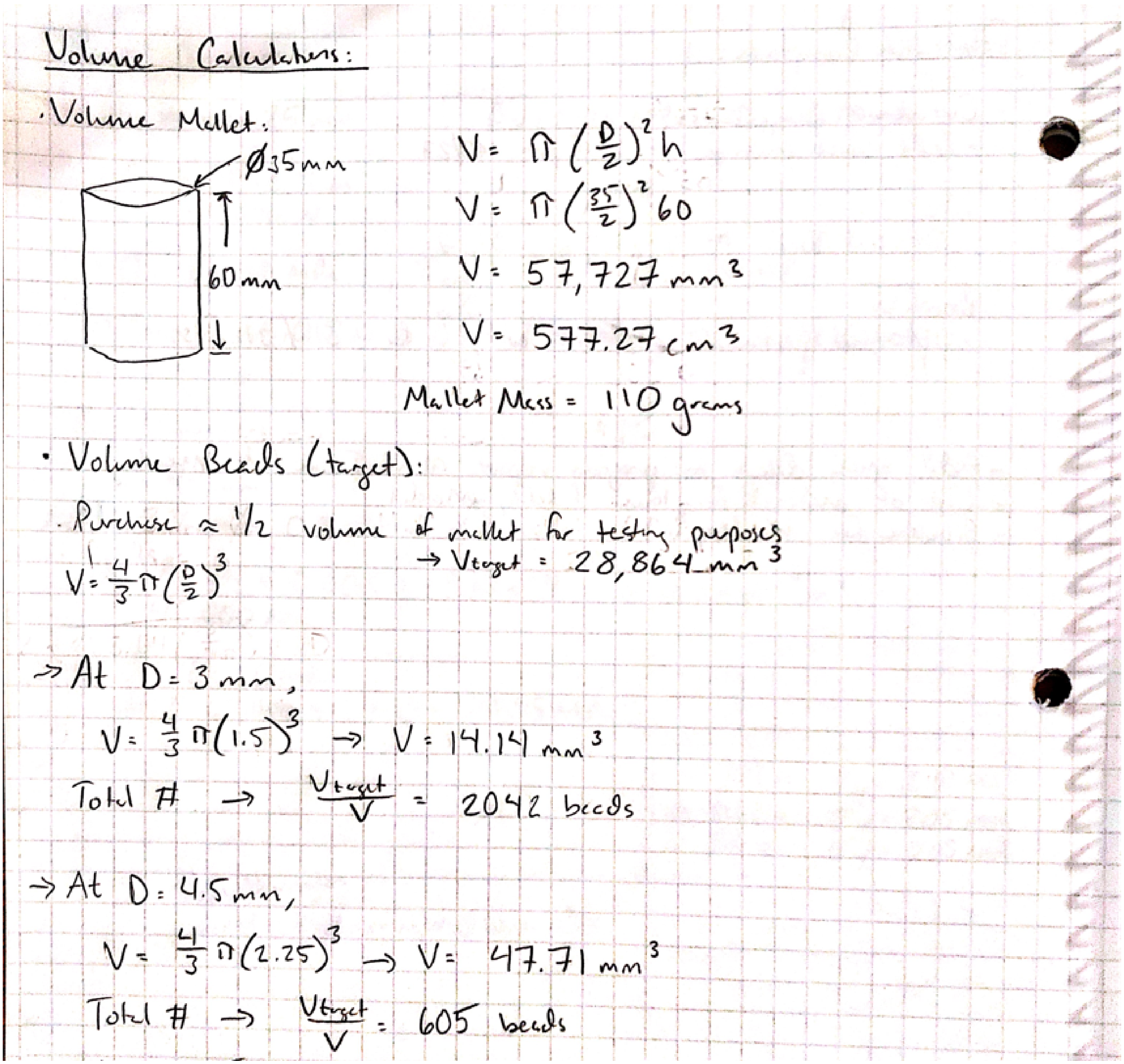


*Figure 1: Calculations for the volume of the inner chamber and beads.*

<u>Discussion of results:</u>

Using the volume of a cylinder equation, it was found that the inner chamber volume is approximately 28,800 mm^3. This was then used as a target volume to determine the amount of beads needed. For a diameter of 3 mm, 2042 beads would be required to fill the chamber. With a diameter of 4.5 mm, 605 beads are required.

Thus, for the first round of testing the 4.5 mm beads will be used. This is also convenient as it is the standard for BB guns, thus is cheaper/easier to acquire a large amount.

**Conclusions/action items:**

The beads at 4.5 mm diameter will be ordered for testing.

# 2021/09/17-Preliminary Design Sketches

CONNOR LINK - Sep 17, 2021, 3:44 PM CDT

**Title: Preliminary Design Sketches - Connor Link**

**Date:** 9/17/2021

**Content by:** Connor Link

**Goals:** Present initial design sketches and initial thoughts/considerations for these designs

**Content:**

Below are several ideas for the design of the hammer, thinking of different factors. These factors include the hammer head design (Figure 1), the filling of the hammer for dead-blow effect (Figure 2), and ideas for an optional casing (Figure 3).

**Note (9/17/21): These ideas were generated after some initial research but a lot of the considerations have not yet been backed by proper research.**

## Head Ideas

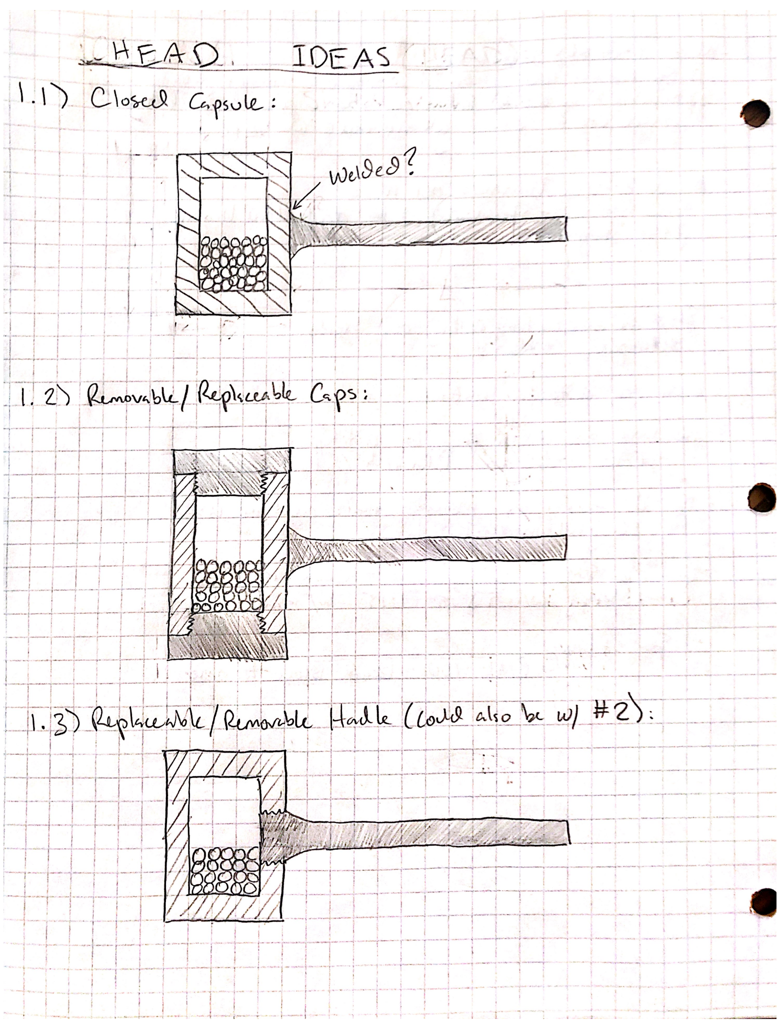


*Figure 1: Three preliminary ideas for the head of the hammer. Drawn/conceptualized on 9/17/2021.*

**Design 1.1 - Classic Dead Blow Design:**

- Following the classic dead blow design with a solid outer head and a hollow inside
- Can only replace the whole hammer
- Does not offer any additional protection for breaking
- Fabrication would be difficult as the shot would need to be added before closing the casing. Maybe could add a small whole before welding on the handle?

**Design 1.2 - Replaceable/Removable Caps:**

- Caps on either side of the hammer that are screwed on/off. Would allow for the replacement of just the ends of the head, which could reduce costs of the hammer overall (and ease of testing).
- May run the risk of becoming unscrewed, this should be tested thoroughly to see if it loosens during use
- May also tighten during use? This could require notches on the caps that would then be removed with the use of an additional tool
- Fabrication would be easier to add the inner filling and replace that if needed.
- Could be cleaned in pieces, but what would we do with the filling?
- Would bacteria be able to better hide in the groves of the screws? Look into research on this and ask professional opinions.
- Are screws more prone to rust? Would the rust lead to a hammer that overall needs to be replaced more often than if it were just one solid piece?

**Design 1.3 - Replaceable/Removable Handle:**

- This is very similar to the concept of Design 1.2. This could also be incorporated with Design 1.2 to make the hammer 4 separate pieces (3 unique pieces) that could all be replaced/cleaned separately.

## Filling (of hollow head) Ideas

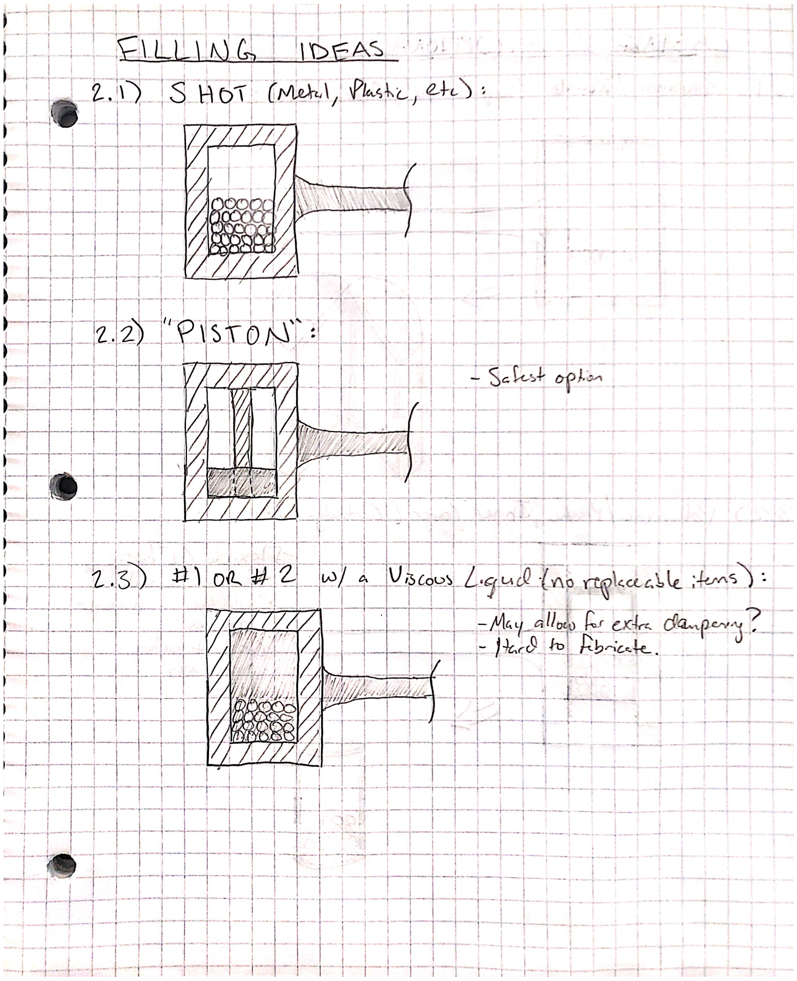


*Figure 2: Three preliminary ideas for the filling of the hammer for the energy distribution (dead-blow effect). Drawn/conceptualized on 9/17/2021.*

**Design 2.1 - Classic Shot Filling:**

- This follows the classic shot idea. I believe (find research or do testing to back this up) that this would allow for a greater energy distribution (thus less recoil/more control) than Design 2.2.
- A major possible consequence of this design is if the hammer breaks (especially during open surgery) the shot may go everywhere and cause a mess (or worse harm to the patient).

**Design 2.2 - "Piston" Filling:**

- This uses a sort of "piston" following along a guide rod
- This would cause less problems if the hammer were to break as it would require a massive break to even escape the core. And in the case of a massive break, it is only one piece (this material would be something that does not harm the body with short exposure).
- I would worry about friction with this hammer, and overall effectiveness of the energy distribution (i.e. would it make a difference).
- If the caps were removable the guide rod would need to be a part of one of the caps
    - This would make 4 unique pieces if we take Design 1.3 and Design 1.2 together
    - Is the guide rod necessary?

**Design 2.3 - Viscous Filling with either 2.1 or 2.2:**

- This would incorporate either Design 2.1 or Design 2.2 as well
- The idea would be to add a viscous liquid into the hollow cavity to better help with energy distribution.
- This could lead to even greater mess, increased difficulty in fabrication, and is it just overkill?

## Casing Ideas (Optional Feature):

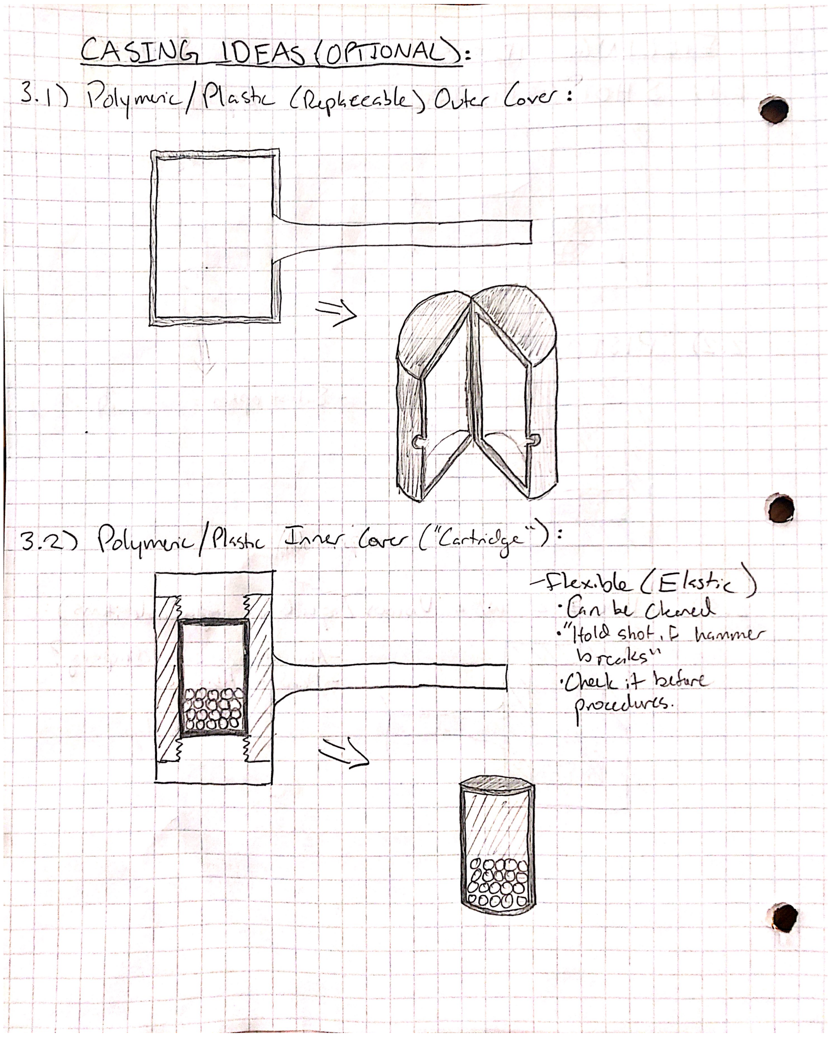


*Figure 3: Three preliminary ideas for the optional casing of the hammer. The goal behind the casing is to provide an extra layer and protect the patient from the bead filling. Drawn/conceptualized on 9/17/2021.*

**Design 3.1 - Outer Cover (Polymer/Plastic):**

- This design incorporates an outer polymer/plastic covering that is attached/removable with a crease/hinge. This would probably need to be a harder plastic.
- The idea is to add extra safety for the patient in which the covering would shatter before the hammer would shatter in an operation (the shot would not go everywhere).
- Can this be cleaned as effectively as having a metal outside? How often would this cover need to be replaced and how much would that cost? Is this overkill?

**Design 3.2 - Inner Cover/"Cartridge" (Polymer/Plastic):**

- This design incorporates an inner covering or sort of "Cartridge". I believe the best option would be to use an elastic polymer that is fabricated with the shot.
  - This would greatly increase the patient safety in the case of the hammer breaking (or unscrewing) during a procedure.
- Elastic material - using elastic material would prove beneficial against high impulse forces (resistance to shattering/breaking in the same manner).
  - This could also contribute to the dampening effect (slightly) that is observed with the shot

  - Would probably still need to be safe for contact with an open body in case of the worst case-scenario --> but should be considered with cost and longevity.
- These could be fabricated directly into Design 1.1, but I think the best use would be to use Design 1.2 (and maybe Design 1.3 as well) for the head.
  - This would create up to 4 unique components (5 separate components) that could all be cleaned/replaced separately.
- This would allow for different types cartridges to be created
  - Prototype testing - could (cheaply?) test different amounts of shot for efficacy
  - Actual Use - could adjust the weight/dampening effect as wanted.
  - Upgrades - would allow for newer dampening technologies to be incorporated in the future or adjustments to be made based on efficacy (long-term clinical testing).
- Is there an increased occurrence of bacteria/contaminants between the hollow inner wall of the hammer and the outer wall of the casing? Can this be properly cleaned? Does it contribute (or even inhibit) to the dampening effect of the shot?

**Conclusions/action items:**

Conclusion:

At first thought I like the incorporation of both Design 1.2 and 1.3 for the head (meaning 4 unique components), and Design 2.1 (the shot) incorporated with the optional Design 3.2 (inner casing), which is drawn in Figure 4. This would allow for the replaceability of different components of the hammer vs. having to replace the whole hammer. Benefits of the inner casing are also discussed above. Although I like this idea, cost considerations and ease of fabrication should be taken into consideration.

- Testing/This Semester - I believe though that the separate pieces would be even easier to fabricate than if it were one whole piece (with minimal cost increase if outsourced).
- These designs should be adapted as more research is done and/or other factors are considered.

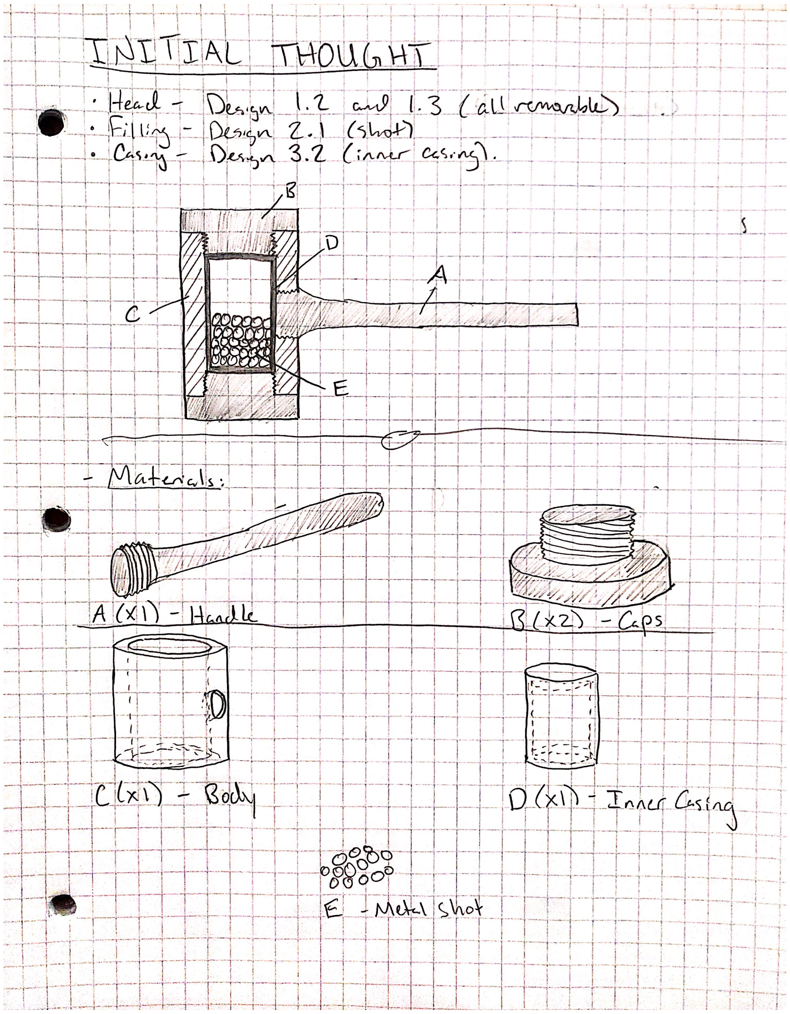


*Figure 4: Preliminary design idea for the overall make-up of the Dead Blow Hammer. Drawn/conceptualized on 9/17/2021.*

<u>Action Items:</u>

- Look into the possibility of self fabrication (Team Lab Green Pass -- my expertise is probably not up-to-par) or outsourcing the work (more expensive but probably worth it -- TIME SENSITIVE)
- Look into the highlighted questions above, particularly:
  - Rust/bacterial problems with the screws vs. smooth surface
- Meet with the team to discuss their ideas and put together a design matrix.

# 2021/10/08 - Preliminary Design Solidworks

CONNOR LINK - Oct 19, 2021, 3:46 PM CDT

**Title:** Preliminary Design for Solidworks

**Date:** 10/08/2021

**Content by:** Connor Link

**Goals:** Model the chosen design in Solidworks

**Content:**

The "Replaceable Caps (with Inner Casing)" design was chosen by the team after the evaluation of the design matrix. I then modelled this in Solidworks with the dimensions discussed in the Calculation of Mechanical Properties page of this notebook. Figure 1 shows this assembly.

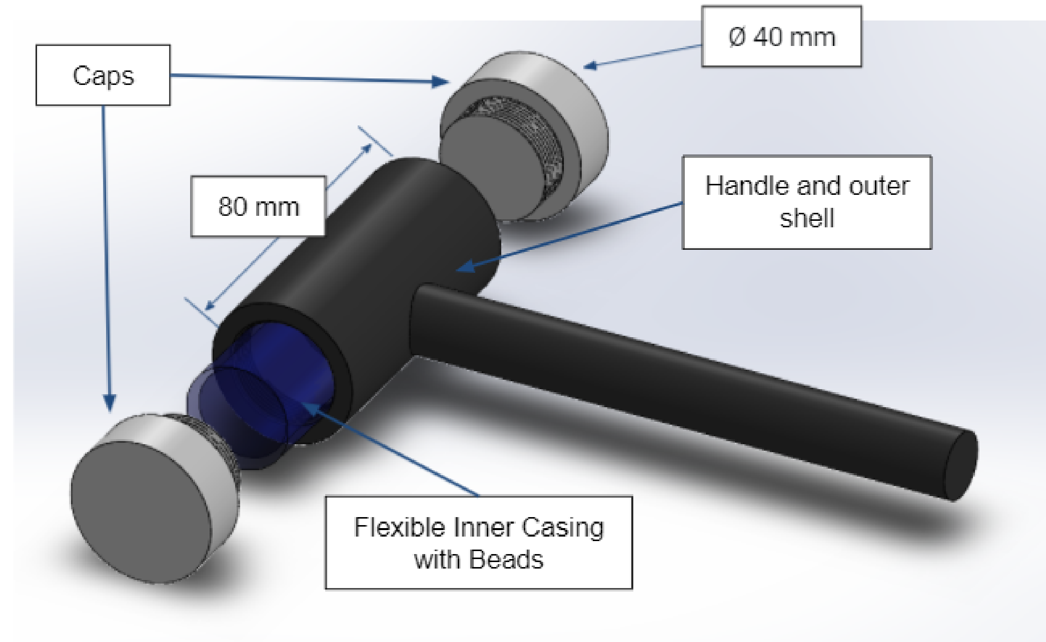


*Figure 1: Solidworks design of the hammer.*

The design consists of 3 distinct parts that were designed in Solidworks: 2 caps, an outer shell with a welded handle, and a flexible inner casing with metal beads. Several important dimensions are shown in Figure 1, these are those of the cap diameter and the length of the outer shell.

**Conclusions/action items:**

The handle should be updated to better fit the hand of the surgeon, instead of just a solid, cylindrical rod.

CONNOR LINK - Oct 19, 2021, 3:47 PM CDT

**End_Cap.SLDPRT(379.7 KB) - download**

CONNOR LINK - Oct 19, 2021, 3:47 PM CDT

**Hammer_Shell.SLDPRT(364.1 KB) - download**

CONNOR LINK - Oct 19, 2021, 3:47 PM CDT

**Inner_Casing.SLDPRT(73.9 KB) - download**

CONNOR LINK - Oct 19, 2021, 3:47 PM CDT

**Hammer_assem.SLDASM(624.3 KB) - download**

# 2021/10/24 - Redesigned Handle

CONNOR LINK - Dec 14, 2021, 1:38 PM CST

**Title:** Redesigned Handle as Designed in Solidworks

**Date:** 10/24/2021

**Content by:** Connor Link

**Goals:** Make edits to the handle for the mallet based on the ergonomics research

**Content:**

The mallet was redesigned to account for maximal ergonomic comfort for the surgeon. The inner chamber was also increased in size in order to provide more volume in which the beads can be placed.

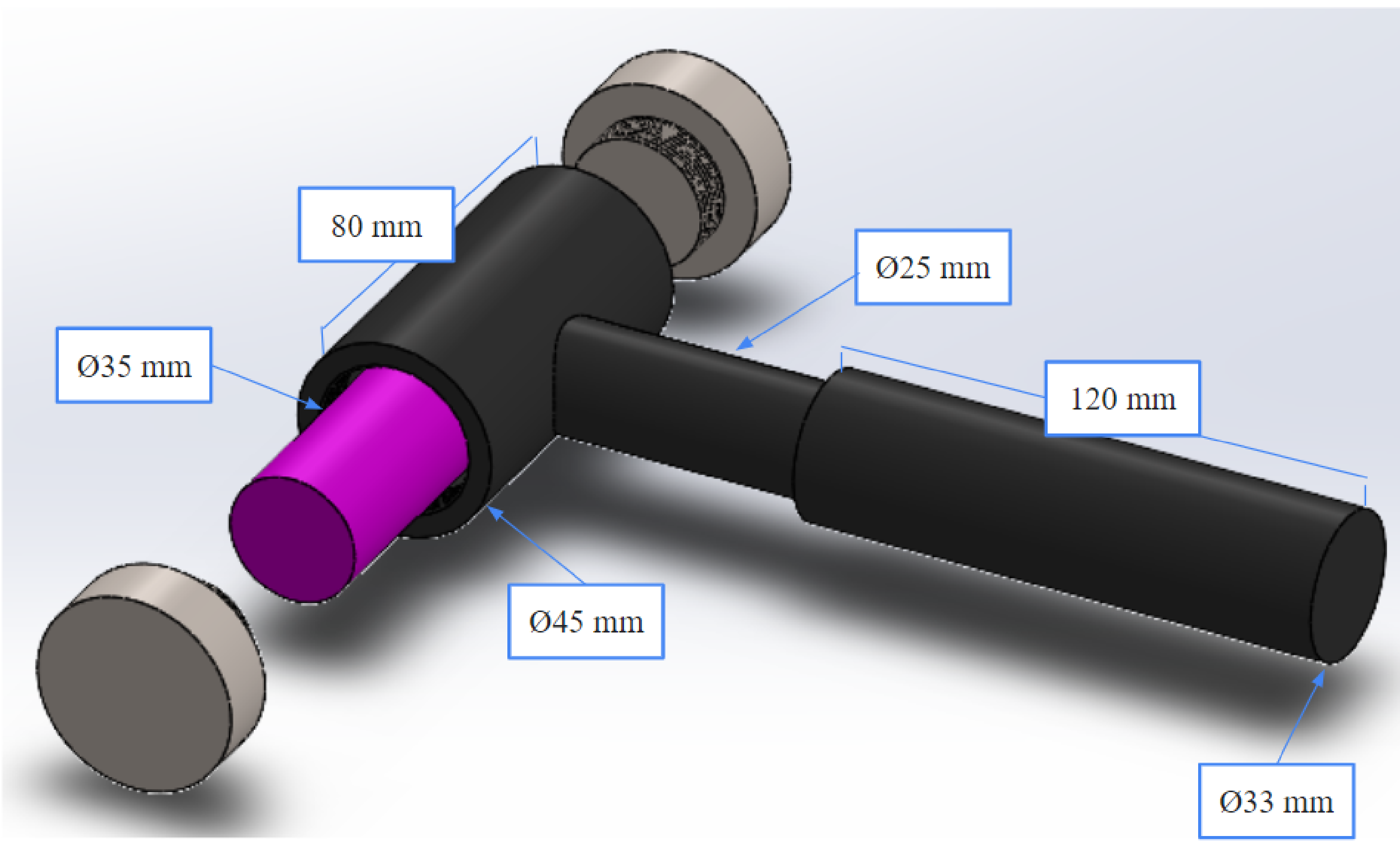


*Figure 1: Redesign of the mallet. This takes into consideration maximizing ergonomic comfort for the surgeon.*

Calculations for the New Dimensions:

Figure 2 shows the calculations for the maximum stresses that will occur. These stresses occur as (1) a normal stress in the shaft where the chamber occurs due to the thin wall (10 mm) and (2) a shear stress in the thinnest part of the handle.

## Stress Calculations (10/24 design)

$$\sigma = \frac{F}{A}$$

- Inner chamber

$$A = \pi R_o^2 - \pi r_i^2 = \pi(45^2 - 35^2) = 800\pi \text{ mm}^2$$

$F_{max}$ = 40,000 N (w/ 1.5 FoS)

$$\sigma_{max} = \frac{40{,}000 \text{ N}}{800\pi \text{ mm}^2} = 15.92 \text{ MPa} = \sigma_{max} \text{ (inner chamber)}$$

- With yield stresses as follows:
  - ss 303 a → $\sigma_y$ = 240 MPa
  - ss 316L a → $\sigma_y$ = 205 MPa
  - ss 316 a → $\sigma_y$ = 205 MPa

This design fits well under the material physical constraints

- Shear in small ∅ of handle:

$$\tau_{max} = \frac{3}{2} \frac{V_{max}}{A}$$

$$A = \pi r^2 = \pi(25)^2 = 625\pi \text{ mm}^2$$

$V_{max}$ = 40,000 N

$$\tau_{max} = \frac{3}{2} \cdot \frac{40{,}000}{625\pi} = 30.56 \text{ MPa} = \tau_{max} \text{ (handle)}$$

*Figure 2: Calculations for the maximum stresses.*

The calculated theoretical stresses are as follows:

(1) The Shaft: The maximum normal stress is 15.92 MPa

(2) The Handle: The maximum shear stress is 30.56 MPa

Compared with the yield stresses of 303 annealed stainless steel (240 MPa) and 316/316L annealed stainless steel (205 MPa), these dimensions fit within the design constraints with a comfortable margin of error.

**Conclusions/action items:**

The team can move forward with these dimensions for testing.

CONNOR LINK - Dec 14, 2021, 1:39 PM CST

**Hammer_Shell.SLDPRT(394.5 KB) - download**

CONNOR LINK - Dec 14, 2021, 1:39 PM CST

**Mallet_Assembly.SLDASM(598.8 KB) - download**

# 2021/10/28 - Motion Study in Solidworks

CONNOR LINK - Dec 14, 2021, 1:51 PM CST

**Title:** Motion Study of the final design for the mallet

**Date:** 10/28/2021

**Content by:** Connor Link

**Goals:** Create a Motion Study to better understand how the beads interact in the chamber

**Content:**

A motion study was created in Solidworks to better visualize how the beads interact inside of the chamber. Two frames of this are in Figure 1 and Figure 2, respectively.

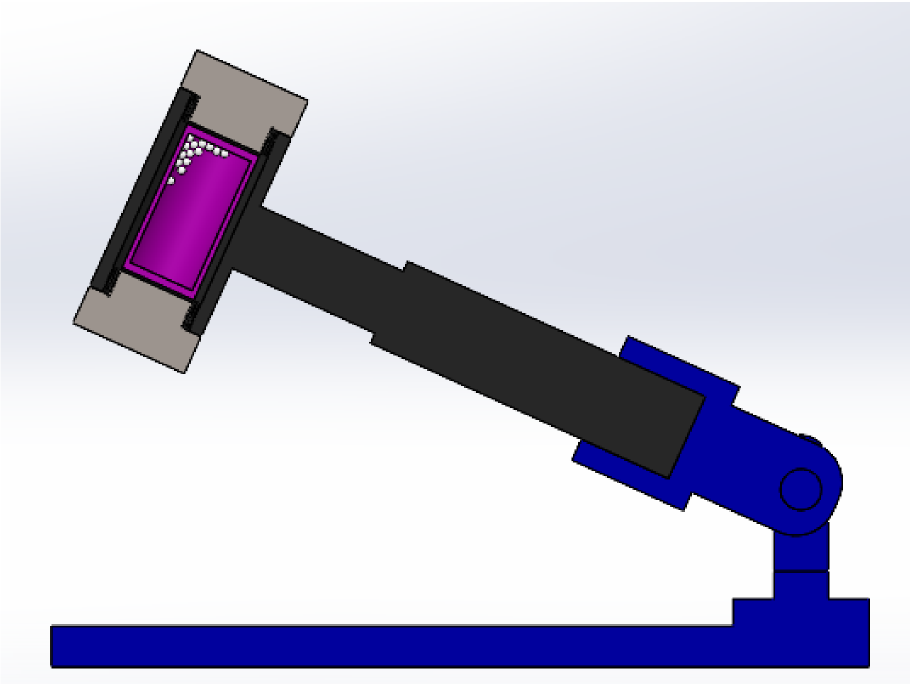

*Figure 1: Screen shot of a frame of the motion study when the mallet is on a downward swing. The beads are visible in the chamber.*

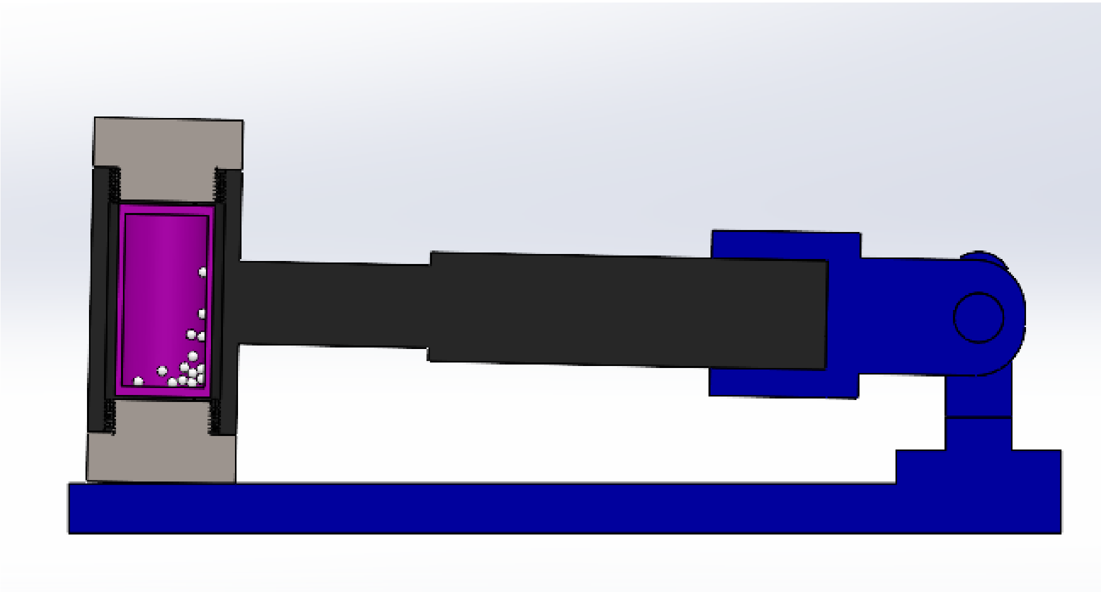

*Figure 2: A screenshot of the motion study upon impact with a surface after a downswing.*

As expected, the beads moved to the top of the chamber during the downswing of the mallet. These beads then quickly struck the bottom surface upon impact with an external surface. This study helps to conceptualize why we expect an increase in impact time with the dead blow hammer.

**Conclusions/action items:**

This study can be presented to others in order to explain the inner workings of the dead blow mallet.

CONNOR LINK - Dec 14, 2021, 1:52 PM CST

**Hammer_assem.SLDASM(881.5 KB) - download**

# 2021/11/25- 3D printed design and beads

**Title:** Discuss the 3D printed mallet

**Date:** 11/25/2021

**Content by:** Connor Link

**Goals:** Discuss the 3D printed mallet

**Sources:** [1] B. Wittbrodt and J. M. Pearce. "The Effects of PLA Color on Material Properties of 3-D Printed Components," *Additive Manufacturing*. 2015. [Online]. Available at: <https://www.researchgate.net/publication/283985639_The_Effects_of_PLA_Color_on_Material_Properties_of_3-D_Printed_Components> (Accessed 16 Nov. 2021).

**Content:**

Materials/Calculations:

The first iteration of the mallet was printed at the UW-Madison Makerspace with PLA plastic. This cost $10.96 for materials. After printing, the mallet was weighed and found to be 107 grams.

The color black was used for the dead blow mallet. The average yield strength is 49.23 +/- 1.18 MPa as reported by Wittbrodt and Pearce [1]. This is sufficient for the various dimensions of the Redesigned Handle").

Pictures:

Figure 1 contains two images for the mallet as printed with PLA plastic.

*Figure 1: Images of the dead blow mallet. The end caps are sealed with epoxy to ensure they do not come apart during testing.*

Filling/Masses

The measured mass of the hammer components (shaft with handle, end caps) was 107 grams. In order to fill the chamber by 50%, 306 beads are required (actually 50.6%). With a mass of 0.: as well.

**Conclusions/action items:**

With a mass that is equal to the empty hammer, conclusions from the testing procedure should be carefully considered. Analyzing the differences in maximum force produced does not tell us r
significance of the difference in impact time when compared to the control mallet.

# 2021/12/08- Force Testing Results/Analysis

CONNOR LINK - Dec 14, 2021, 2:59 PM CST

**Title:** Analysis of the Force-Time testing data that occurred on 12/7/2021

**Date:** 12/8/2021

**Content by:** Connor Link

**Goals:** Use Matlab to analyze the data in the force plate testing

**Content:**

Equations/Matlab Code Explanation

The data is presented as forces in the x, y, and z directions with a column containing each frame of data collection. With a collection frequency of 1000 Hz, data is sampled with a reading at every 0.001 seconds (meaning each row in the CSV file occurs every 0.001 seconds). In order to determine the force, the magnitude of all three force directions was calculated with Equation 1:

F_resultant = (Fx^2 + Fy^2 + Fz^2)^0.5 (Equation 1)

Since each test contained 3 consecutive strikes, the maximum force of each strike was centered so that 0.8 seconds of data was captured for each individual strike. This totaled 15 strikes for the dead blow mallet and 15 strikes for the control mallet. These values for resultant force were placed into a CSV file ("ResultantForce.csv" as attached) for ease of analysis in the future using code provided in "deadblow.m" (as attached).

The code titled "singlePeaks.m" (as attached) was used to create plots and perform statistical analysis on the data. This is presented below.

Results

Figure 1 contains a force-time plot with a total of 15 strikes by the control mallet. Figure 2 contains the force-time plot with a total of 15 strikes by the dead blow mallet.

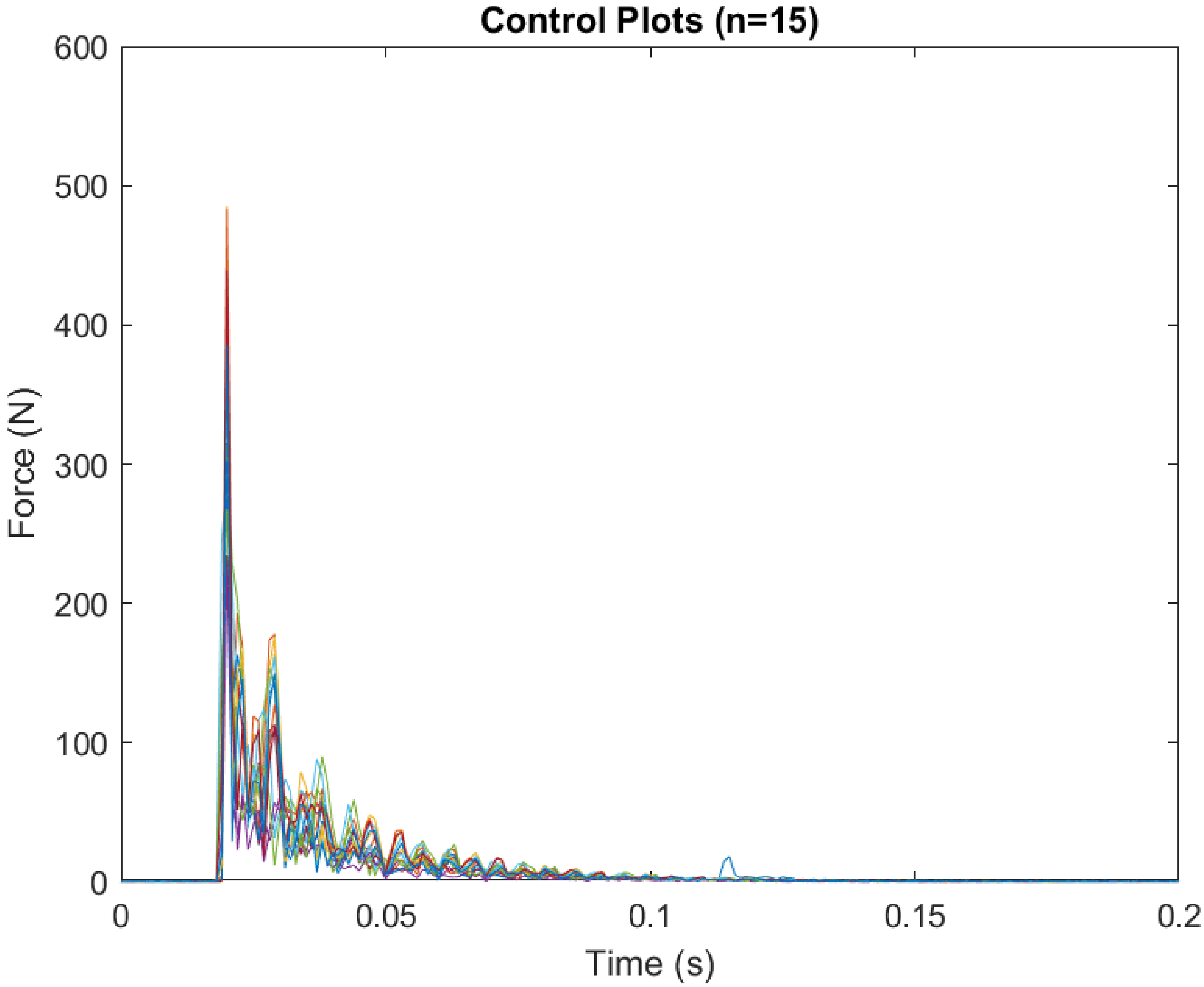


*Figure 1: Force-time plot for the control mallet.*

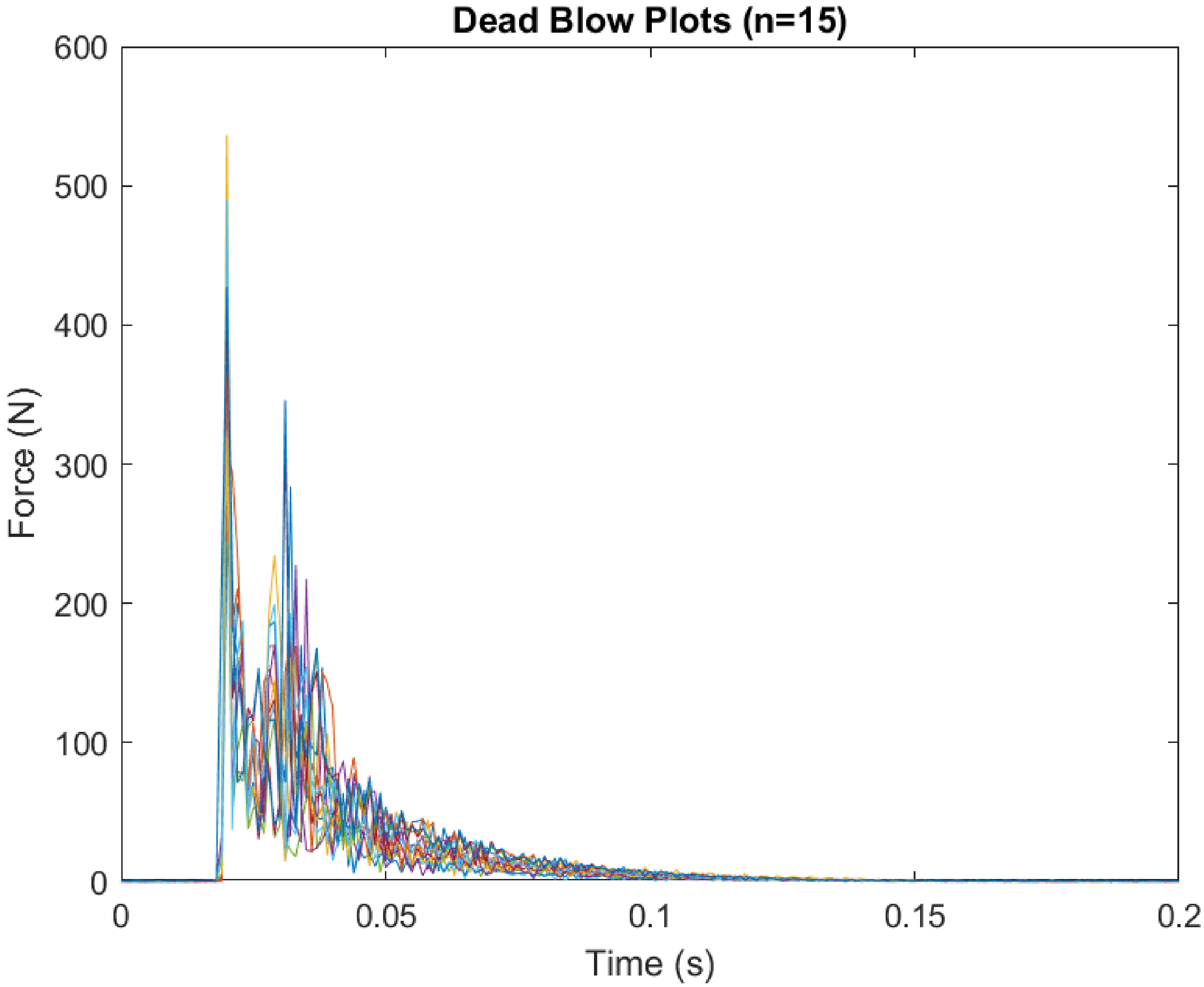


*Figure 2: Force-time plot for the dead blow mallet.*

Through visual inspection of Figure 1 and Figure 2, it appears that the dead blow mallet generally achieves a greater maximum force upon impact. However, with the weight differences and from the crude testing procedure, no conclusions can be made with confidence about the cause of this difference.

Figure 3 contains a force-time plot for the average values of all strikes for both the control and dead blow mallets. Figure 4 is a similar plot to Figure 3, however, each of the values in the plot are normalized for the maximum striking force that the test achieved (by dividing the value by the maximum force).

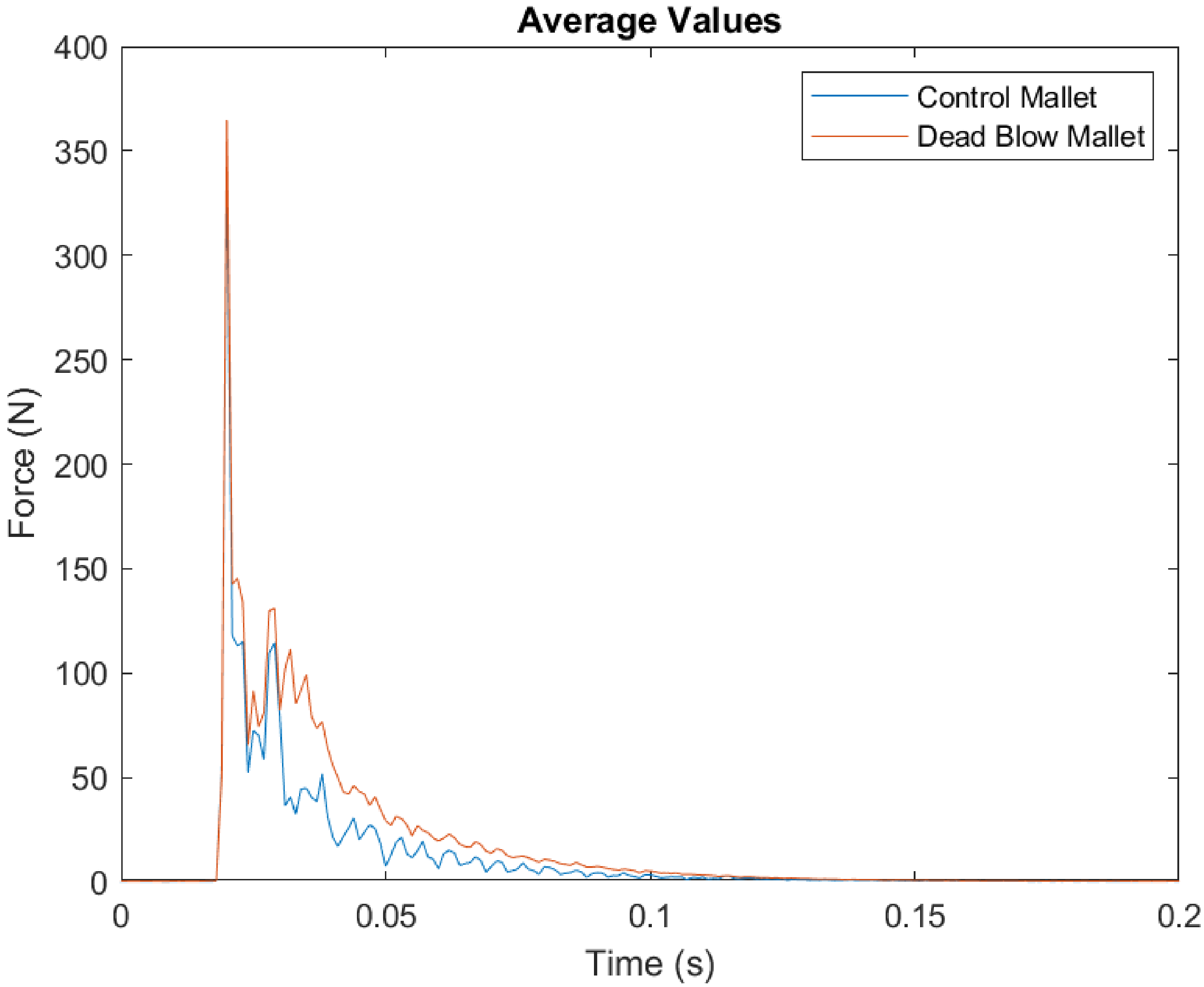


*Figure 3: Force-time plot for the average force characteristics of both the dead blow and control mallets during testing*

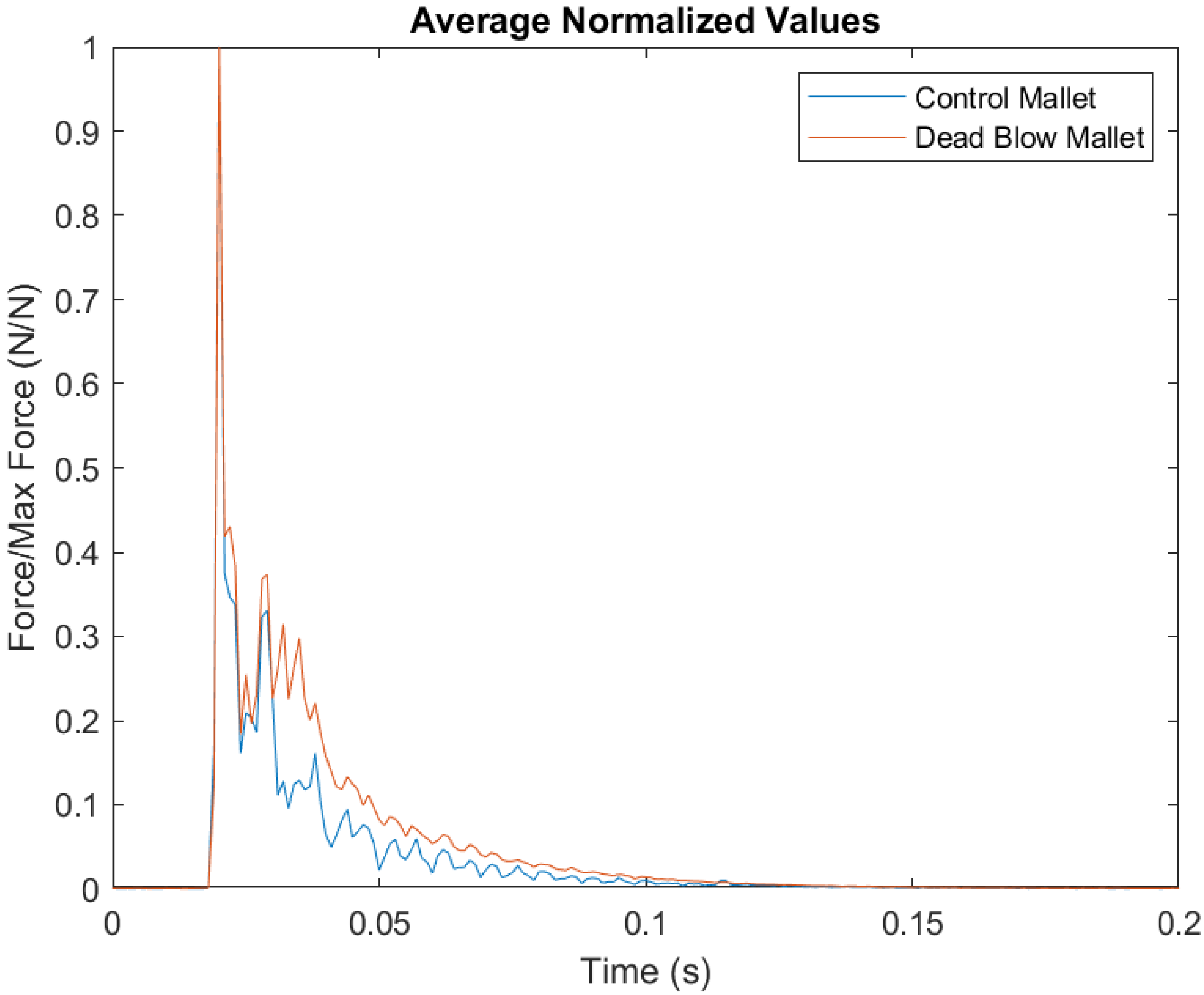


*Figure 4: Force-time plot for the average normalized force characteristics of both the dead blow and control mallets.*

Through visual inspection of Figures 3 and 4, it can be seen that the dead blow mallet appears to have a longer time of appreciable impact. This is further discussed with statistical analysis methods below.

Statistical Analysis

The impact time for each test was calculated by finding for how many seconds the force was over 5N of force for each test. The mean (+/- the standard deviation) for the control mallet was 0.061 +/- 0.007 seconds and for the dead blow mallet was 0.077 +/- 0.009 seconds.

A two-tailed t-test was performed to determine any significance between the difference of mean impact times. A p-value of approximately 1e-5 was returned through Matlab. This indicates that the dead blow impact time lasted longer than the control mallet, which aligns with our hypothesis.

**Conclusions/action items:**

The impact time was found to be significantly different between the two groups through a two-tailed t-test. This gives confidence in our current design dimensions, however, further testing with a metal mallet is required before any significant conclusions can be made. This will occur early in the Spring 2022 semester.

CONNOR LINK - Dec 14, 2021, 2:35 PM CST

```
% Analysis of Dead Blow Testing
% 12/7/2021
% By: Connor Link
% BME 400, University of Wisconsin-Madison

close all;
clear all;

%% Set up for each test (CHANGE EACH TIME)
file = readmatrix('HammerTesting1.csv');
plotName = 'Force-Time Control #1';
imageName = 'Control_1.png';

%% Gather the data from the CSV files

x = file(:,4);
y = file(:,5);
z = file(:,6);

force = sqrt(x.^2 + y.^2 + z.^2);

%% Get the time data
% Bertec force plate samples at a rate of 1000 Hz. This means that there is
% 1000 data points per second.
frequency = 1000; %Hz
vector = (1:length(force))';

time = vector/frequency;


figure
plot(time,force);
ylabel('Force (N)');
xlabel('Time (s)');
title(plotName);

% saveas(gcf, imageName);


%% Create a CSV file with all resultant forces as rows
writematrix(force', 'ForceRows.csv');

for i = 2:10
    val = num2str(i);
    fileName = strcat('HammerTesting',val,'.csv');
    data = readmatrix(fileName);

    x = data(:,4);
    y = data(:,5);
    z = data(:,6);

    force2 = sqrt(x.^2 + y.^2 + z.^2); %This is a column vector
    writematrix(force2','ForceRows.csv','WriteMode','append');

end

%% Create a Matrix with all the force data and save as csv with columns

matrixRows = readmatrix('ForceRows.csv');
matrixCols = matrixRows';
matrixCols(isnan(matrixCols))=0; %Changes the NaN values to 0

writematrix(matrixCols, 'ResultantForce.csv');
```

**deadblow.m(1.4 KB) - download**

CONNOR LINK - Dec 14, 2021, 2:35 PM CST

```
%% Open up the resultant force data (ResultantForce.csv)
file = readmatrix('ResultantForce.csv');

% [max1_1,A1] = max(file(700:1100,9));
% [max2_1,A2] = max(file(1500:2000,9));
% [max3_1,A3] = max(file(2400:3000,9));

% Test 1: Control
peak11 = file(1393:2193,1);
peak21 = file(2551:3351,1);
peak31 = file(3649:4449,1);

% Test 2: Control
peak12 = file(81:881,2);
peak22 = file(1123:1923,2);
peak32 = file(2097:2897,2);

% Test 3: Control
peak13 = file(727:1527,3);
peak23 = file(1731:2531,3);
peak33 = file(2713:3513,3);

% Test 4: Control
peak14 = file(721:1521,4);
peak24 = file(1707:2507,4);
peak34 = file(2655:3455,4);

% Test 5: Control
peak15 = file(435:1235,5);
peak25 = file(1353:2153,5);
peak35 = file(2201:3001,5);

% Test 6: Dead Blow
peak16 = file(621:1421,6);
peak26 = file(1592:2392,6);
peak36 = file(2541:3341,6);

% Test 7: Dead Blow
peak17 = file(476:1276,7);
peak27 = file(1321:2121,7);
peak37 = file(2212:3012,7);

% Test 8: Dead Blow
peak18 = file(539:1339,8);
peak28 = file(1373:2173,8);
peak38 = file(2198:2998,8);

% Test 9: Dead Blow
peak19 = file(583:1383,9);
peak29 = file(1434:2234,9);
peak39 = file(2284:3084,9);

% Test 10: Dead Blow
peak110 = file(657:1457,10);
peak210 = file(1525:2325,10);
peak310 = file(2370:3170,10);

%% Create Plots for the Data
freq = 1000; %Hz
time = [1:801]/freq

figure(1)
plot(time,peak11);
```

**singlePeaks.m(6.6 KB) - download**

CONNOR LINK - Dec 14, 2021, 2:35 PM CST

**ResultantForce.csv(444.7 KB) - download**

# Major Hip Replacement

ISAAC KRAUSE - Oct 20, 2021, 12:44 PM CDT

**Title: Major Hip Replacement**

**Date:** 9/20/21

**Content by:** Isaac Krause

**Present:** NA

**Goals:** Although we are mainly focusing on knee replacements, the hammer used can also be used in major hip replacements. So it would be ideal to research these replacements and understand them in case we are asked about it in the near future.

**Content:**

**Total Hip Replacement vs Hip Reconstruction**

Hip Reconstruction

Arthroscopy

- Minimally invasive procedure where the hip is repaired through a small incision

Periacetabular osteotomy (PAO)

- Hip bone is reshaped and fixed in a new position
- Helps distribute weight more evenly

Resurfacing

- Surgeons resurface the head of the femur bone and hip socket with a smooth metal
- Helps reduce pain and improve mobility

Cartilage Transplant

- Diseased portion of the hip is removed and undamaged cartilage is transported

Total Hip Replacement

The surgeon replaces cartilage that has deteriorated beyond repair with an artificial joint that the doctor selects to best meet the patients needs

https://utswmed.org/conditions-treatments/hip-reconstruction-and-replacement-surgery/

**How is the Total Hip Replacement Performed?**

Hip Anatomy

Hip Joint

- The hip is a ball and socket joint
    - The ball at the top of your femur is called the femoral head
    - The socket is a part of your pelvis
- This joint allows movement forwards, backwards, and sideways
- Also also leg rotation

Surgical Approach Methods

Posterior Approach (more common) - below is a link to a video on how the posterior approach is conducted

https://player.understand.com/hss/en/a9a23aad-281c-45d6-afcd-80ad4cfa2502/3e5caddb-4e86-422c-925d-3e3662646360

Anterior Approach

https://www.hss.edu/condition-list_hip-replacement.asp

Surgery

Hip replacement surgery is usually done either under general anaesthetic (you're asleep throughout the procedure) or under spinal anaesthetic (you're awake but have no feeling from the waist down).

Sometimes you may have an epidural, which is similar to a spinal anaesthetic.

Once you've been anaesthetised, the surgeon makes a cut (incision) of up to 30cm over the side of your hip.

The upper part of your thigh bone (femur) is removed and the natural socket for the head of your femur is hollowed out.

A socket is fitted into the hollow in your pelvis. A short, angled metal shaft (the stem) with a smooth ball on its upper end (to fit into the socket) is placed into the hollow of your femur. The cup and the stem may be pressed into place or fixed with bone "cement".

The operation takes up to 2 hours.

https://www.nhs.uk/conditions/hip-replacement/what-happens/

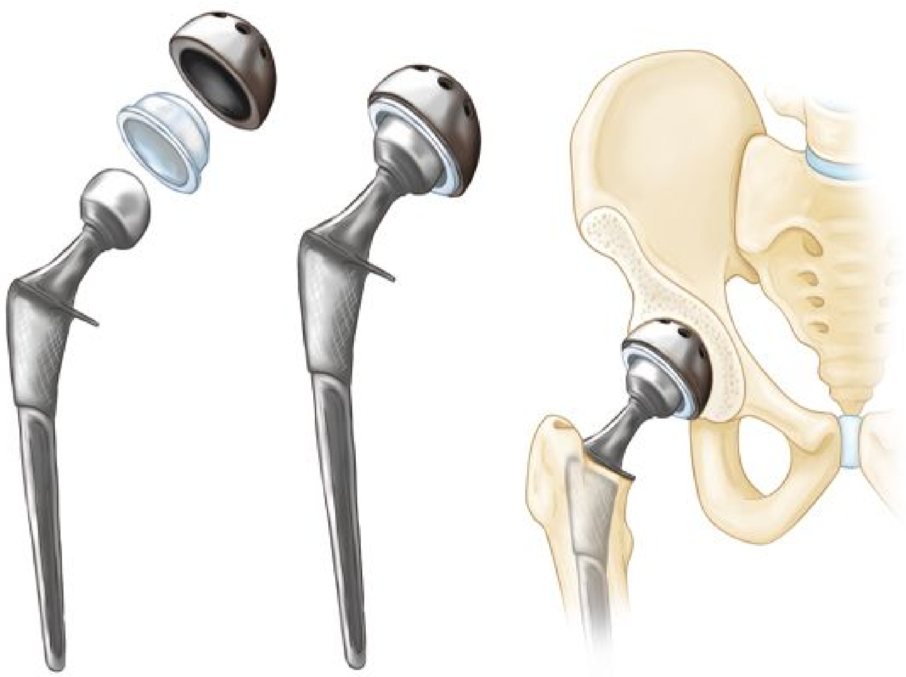

Figure 1: Total Hip Replacement

**Conclusions/action items:**

Everything above can be taken into account once our design for a knee-replacement focused is created to see if it needs to be tweaked to perform the same for hips.

# Types of Materials for Hip/Knee Replacements

ISAAC KRAUSE - Oct 20, 2021, 1:38 PM CDT

**Title: Different Materials**

**Date:** 9/20/21

**Content by:** Isaac Krause

**Present:** NA

**Goals:** Discuss what kinds of materials are used for hip/knee replacements and how they are chosen.

**Content:**

Materials used in the implant can vary depending upon a variety of factors including...

- Patient age
- Patient activity level
- Surgeon preference
- Particular deformities/abnormalities of the hip or knee

Ceramic on Plastic (polyethylene):

Uses metal parts that fit within the bone, but the bearing surface for the ball or head is made of ceramic material. The socket bearing is made of a special plastic (polyethylene). Ceramic head implants are designed to be the most resistant to wear (they are very hard and smooth). The ceramic head will also cause less wearing of the polyethylene. These are used for a majority of total hip replacements.

Ceramic on Ceramic:

More popular 10 years ago because it had very low wear. However, it could create an intolerable squeaking that would require a surgical revision.

Metal on Plastic:

The metal femoral head is the most common type of head implant. The metals commonly used are cobalt-chromium, titanium, zirconium, and nickel. It is the least expensive type of implant and has the longest track record for safety and implant lifespan. There is no risk of the metal breaking. The only downside is the small risk of reactivity to the metal in the femoral head.

Cartilage on Cartilage:

Most exciting yet distant type of hip replacement. Involves a fully biological cadaveric total hip replacement. It is limited by the cost of the cadaveric tissue and the excellent outcomes with tradition hip replacement.

https://www.jointpreservationinstitute.com/blog/what-are-the-best-materials-for-joint-replacement-24337.html

**Conclusions/action items:**

This will give us a better understanding of why certain types of replacements are used

# Dead Blow Hammer (Construction)

ISAAC KRAUSE - Oct 20, 2021, 12:16 PM CDT

**Title: Dead Blow Hammer**

**Date:** 9/12/2021

**Content by:** Isaac Krause

**Present:** NA

**Goals:** Describe and research the different aspects of a Dead Blow Hammer currently used in the construction industry to gain a better understanding of how it can be implemented into the medical industry.

**Content:**

*A Dead Blow Hammer, shown in Figure 1, is a special type of mallet designed to deliver strong blows to a delicate target with minimal rebound and damage radius.

*Figure 1: Dead Blow Hammer with Plastic Casing*

**Components of the Dead Blow Hammer**

Head of the Hammer

- Hollow
- Filled with shot (steel) beads
    - Allows the force to be spread out over a greater amount of time; thus reducing rebound and providing minimal damage to the surface
    - Tough and can be used multiple times without damage
    - Cost effective
    - Generally made from molten steel

Grip/Shaft

- Most have a non-marring plastic casing around the hammer
- Grip is often unweighted

**How Does the Hammer Reduce Rebound?**

As previously mentioned, the shot beads within the hollow head of the mallet allow the force to be spread out over a greater amount of time. As the mallet is swung towards its target, the shot in the head cavity will collect towards the opposite side in the head similar to how one can "fall up" in a dropping elevator. At the instant the mallet strikes its target, the shot it projected towards the target-side of the head. Whereas a rubber mallet would rebound away from the target at this instant, a dead blow continues to deliver an addition force throughout a greater amount of time.

Sources:

"Bead Blasting: Shot Blast Inc.." *Shot Blast Inc*, 24 Mar. 2020, https://shotblastinc.com/bead-blasting/.

Stuart, et al. "Intro to Dead Blow Hammers." *ToolGuyd*, 28 May 2021, https://toolguyd.com/intro-to-dead-blow-hammers/.

**Conclusions/action items:**

These attributions of the Dead Blow Hammer are very much in line with what we are looking for in our hammer. The biggest and most important part being the minimal rebound. This will help reduce the strain put on the surgeons wrist, elbow, and shoulder joints. A key requirement for our design.

# 2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

**Title:** Descriptive title (i.e. Client Meeting)

**Date:** 9/5/2016

**Content by:** The one person who wrote the content

**Present:** Names of those present if more than just you (not necessary for individual work)

**Goals:** Establish clear goals for all text entries (meetings, individual work, etc.).

**Content:**

Contains clear and organized notes (also includes any references used)

**Conclusions/action items:**

Recap only the most significant findings and/or action items resulting from the entry.

# 2014/11/03-Template

John Puccinelli - Nov 03, 2014, 3:20 PM CST

**Title:**

**Date:**

**Content by:**

**Present:**

**Goals:**

**Content:**

**Conclusions/action items:**