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# An Interchangeable Architecture For Shear And Compression Of Soft Materials

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## Introduction

Numerous studies have mechanically tested tissue, in human, animal settings, and simulation-based analysis [1]. Testing tissue is of importance to many fields: reconstructive surgery can use material properties to aid in creation of tissue substitutes and biomechanical engineers can use properties to simulate injury in human body models, to name a few. Injury of tissue can occur when the cells are exposed to high levels of shear and compression forces. However, much of this assessment must be a priori due to the dangerous conditions revolving injury. A current gap in work exists for an inter-modal testing methodology of tissue between compression and shear modes. Gerhard Sommer et. Al. created multi-axial testing methodology for adipose tissue, with a tensile test fixture and tri-axial shear methodology [2]. These two approaches were applied to tissue and results were observed under histology. Animal tissues, specifically porcine adipose tissue has been used in numerous studies; making it a recognized alternative to human adipose tissue, which is difficult to use due to the protocoling guidelines surrounding it [3]. Iatridis et. Al. created a tension test harness for adipose tissue in male rats [4]. More testing for material properties exists, beyond principle motions like tension and compression. Comley and Fleck performed “trouser-tear” styled testing in order to see the cellular effect of tearing adipose tissue, done in the porcine adipose setting [5]. Budday performed inter-modal testing in different regions of brain tissue [6]. The commonality of these papers is that they do not detail on the development and operation of their testing architecture. This paper seeks to focus discussion around a novel formulation of a testing methodology for soft materials, such as tissue or gel-like substances. A major concept that extends this approach coupling the literature is that the testing is performed under both compression and shear modes, interchangeably. Additionally, we seek to show versatility for a wide number of implementations, such as for testing where obese occupants are exposed to a variety of unconventional, extreme conditions in motor vehicle crashes, as demonstrated in [7,8].

## PROBLEM FORMULATION

The testing of soft materials (such as tissues) present a multitude of challenges, such as uniformity of sample preparation, maintenance of sample integrity during transitional stages, and bio-fidelity to system being modelled. Thus, we must create an architecture that resilient under all the three aforementioned conditions. The below figure shows the top-level overview of the overall system and interdependencies. The green processes are functions that are performed by the testing assembly, which are encapsulated by the given test architecture (yellow box), which is the discussion of this work. Gray images are ancillary input/outputs of the system. Blue arrows are processes; they are all relationships that are facilitated by the operator with assistance from the test architecture.

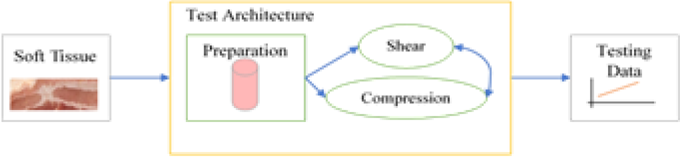

**Figure 1: System architecture**

With the three criteria mentioned above, the first two are covered by the test architecture itself. “Uniformity” (of sample preparation) refers to the idea that each harvested tissue must be able to be processed in a fashion such that each sample is consistent in: height, width, and mass. This contributes to reducing variability in testing results due to differing sample attributes such as boundary conditions and very small differences in aforementioned physical features. The second “Maintenance” aspect is facilitated through the double-sided arrow. Transitioning from shear to compression and vice-versa is the most sensitive procedure in the entire architecture. Our system has preemptively implemented measures to protect the specimen during this section. This reduces error in testing as deformation is minimized during transition (such that the sample does not deform under its own gravity during any transfer).

# Method

The testing is divided into combinations of three major sectors: preparation, mounting, and transition stages. Preparation refers to the concept of standardizing tissue samples to be uniform for testing. Testing is the concept of exposing the samples to conditions designated by the context of the research problem. Lastly, transition refers to the procedure for a single sample to change testing modes, from compression to shear or vice versa.

## Sample Preparation

In order to prepare the sample while ensuring the uniformity paradigm, we implemented a two-step process for production of cylinder-shaped specimens. Cylinders were chosen for easy boundary conditions to computationally model in cylindrical coordinates. The sample is punched from a slab of porcine tissue (designed to regulate the width of the sample), then is standardized using the cutting mechanism (designed to regulate the height), as seen below. The cutting mechanism has three top and bottom pieces each, a cylindrical recess inside accompanied by slits for thin razors. The bottom pieces are bolted in place to ensure the recess remains the same height. Once the punched tissue is placed inside the recess, the three top pieces are replaced. After, thin razors will enter the slits, cutting the sample.

## Sample Mounting

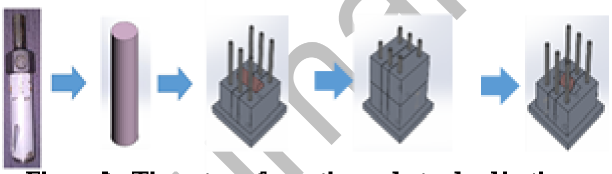

**Figure 2: Tissue transformation and standardization (left to right: punch, sample, cutting mechanism)**

The testing will require a variety of coordinating components to ensure the maintenance aspect previously described can be ensured. The material testing system we employed for this task was a TA Instruments Bose ElectroForce LM1 TestBench. The Bose Machine used one top staged uniaxial actuator to expose the sample to programmed conditions (e.g. preconditioning, ramp-and-hold, stress-relaxation). We bounded the lower stage with a load cell, both of these connections a 10/32” threaded screw. The three major components are shown in Figure 3. The protocol for mounting the sample to compression testing is as follows:

1. The actuator plates (in blue in Figure 3) will screw on to both the actuator and load cell threads.
2. One face of the prepared sample is glued onto the sample plate, orange in the above figure. The sample plate then slides with the actuator plate on the bottom, and is screwed bottom-up through four screws on the corners.
3. The other sample plate is pre-glued and then screwed top down to the top actuator plate.
4. The test machine is then commanded to move downwards until a user-specified pre-load.

## Sample Transitioning

In order to change between modes, the sample plates must maintain a consistent distance to each other, accomplished by the bridge plates. Given that the example started in compression, the aforementioned protocol shows the compression to shear transition. However, the reverse can easily be derived. The transition protocol is as follows:

1. The bridge plates are screwed onto corresponding holes on the sample plates, on both sides.
2. Once the top and bottom screws (four each) are removed from the actuator plates, the “sandwich” of sample plates and sample are removed and are reserved.
3. Both the actuator plates are unscrewed from the actuator or load cell, respectively.

4. The lower stage is translated arbitrarily laterally. We had a two-dimensional stage to facilitate the process.
5. The actuator plates are then re attached using the side set of holes on to both actuator and load cell.
6. After, reattach the sample plate on the side of the lower stage, using the four formerly bottom holes.
7. Translate the bottom laterally in the opposite direction such that the far size sample plate is flush with the corresponding actuator plate, and screw the plates together.

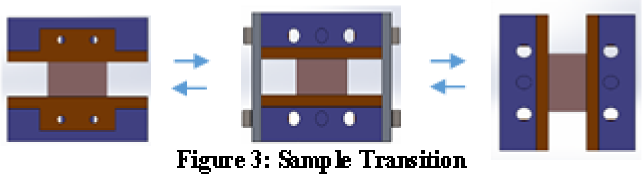

Figure 3: Sample Transition
(blue: actuator plates, orange: shear plates, gray: bridge plates)

8. Unscrew the bridge plates.

## RESULTS

This paper presented a novel methodology for interchangeable testing between shear and compression in one dimension. Divided into two stages, a sample is prepared and standardized, then mounted and tested between both shear and compression. This is employed with a use case of porcine adipose tissue, which can model human adipose tissue under a variety of conditions. Future work for the enhancement of this test fixture includes: support for concurrent shear and compression, addition of a water bath mechanism to maintain hydration under testing, and support for specimens without the need for gluing.

## Acknowledgements

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