Musical Drum Prototype Structural Analysis Estimation Through Change in Infill Percentage

MAE 301 Final Project

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Experiment Performed: Tuesday, April 16th, and Wednesday, April 17th, 2019 1pm MST

Report Due: Sunday, April 26th, 2019

Introduction

Music Therapy has been shown to be an excellent method of treatment for Autism Spectrum and Sensory Disorders by the American Music Therapy Association[1]. "Researchers have discussed advanced music memory, responsiveness, and aptitudes within this population; more recent studies show that individuals with ASD (Autism Spectrum Disorder) may have a heightened musical aptitude and sensitivity to musical elements, yet similar skills of music perception as compared to typically developing peers"[1]. Dynamic Links, a music therapy center in Oakwood, Illinois describes music therapy as working the best when students receive feedback for multiple senses - not just auditory[2]. This is shown in the instruments the children prefer the most consistently - the cabasa, a handheld maraca-like object with metal beads that click together when rubbed but do fall out on occasion, and the ocean drum, a large, heavy drum with a clear head and beads that can be felt through the fabric on the bottom of the drum [2]. The Djambe Autism Therapy Drum development team at Arizona State University aims to construct a drum for use in these therapeutic sessions that integrates visual, haptic, and auditory feedback in a safer, more captivating drum than either of the previously described solutions.

An integral part of this drum will be its sturdiness and weight. This drum should withstand the pressure applied by chaotic small children but be lightweight enough for ease of transportation by the teacher without posing a threat to the safety of the children. This drum is to be estimated by 3D printed cylinders, extruded by a Makerbot Replicator+, set to scale of the final product of measurements - 16inch diameter and 7 inches in height, with measurements of 4.375mm in height and a diameter of 10mm [3]. The drum has a smooth topography and the filament was PLA as it is the most highly used filament type in the Fulton 3D Print Lab, made for a simple testing process, and was recycled at the conclusion of the test. The effective strength of these 3D printed cylinders will be tested in compression by an INSTRON Series IX version 8.25.00, up to a maximum load of 5kN until the material reaches the elastic limit. This limit will approximate the permanent fracture of internal support structures of the drum, and indicate the maximum force the drum can withstand. The amount of support structures within a structure will change both the maximum amount of force it can withstand as well as the weight of the structure.

Given the nature of 3D printing, the percent infill will approximate the relative proportion of support structures to the overall structure of the drum. It is generally accepted within the 3D printing community that 30% infill exceeds the strength required for most non-load-bearing applications, and that between 30 - 60% the ratio of improved strength to added infill tapers off [4]. The difference in distribution means of fracture strength for 30 and 40 percent infill was hypothesized to be 1.5 that of the difference in distribution means for fracture strength of 50 and 60% infill. The structure strength will increase exponentially with increase in percent infill until, at an unknown point near 50%, the structure strength tends to a horizontal asymptote. (10% is much stronger than 5%, but 70% and 100% are practically identical in structure strength in compression.) The variation in fracture strength was assumed to not change with percent infill. I assume that the variation of each distribution is a real number which will be approximated by the sample variance for all samples as each sample is the same structure design and filament type. As a result, I will be using a two sample student's t test with a pooled variance to test my hypothesis. In the event that I cannot reject my hypothesis with a two tailed alpha of 10%, I will assume that the point at which additional supports become redundant will be close to 50% and will compare the change in fracture strength/ weight ratio of 40% to 50% to 30-40 and 50-60 to confirm which region of my interval this occurs in. If this can be rejected, I must conclude that I would need to perform further testing to determine if I can utilize less than 30% infill or if I must have higher than 60%. The percentage infill required indicates the minimum support to weight ratio required to optimize the drum structure.

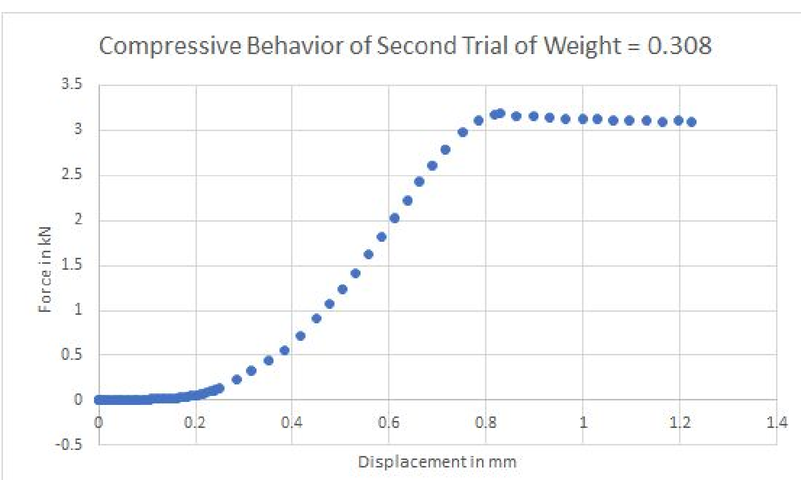
The inputs for this hypothesis test are the infill percentages, and the output is the corresponding elastic limit of each of these infill percentages. There will be two trials for each infill percentage. While this is a pitifully small number of tests, 3D printing with the Fulton 3D Print Lab can be a time consuming process and this will merely attempt to estimate the similarity of distribution means.

Procedures

A cylindrical specimen of measurements of 4.375mm in height and a diameter of 10mm is loaded into the INSTRON Series IX version 8.25.00 for a manual compressive test without an extensometer and a crossheed speed of 2.00000 mm/min. A inch square thin steel plate is placed atop the specimen to ensure equal distribution of force across the specimen. The simulation is ran until the computer software passes the elastic limit, when the specimen is unloaded but now permanently plastically damaged. Any further testing with such small samples simply quishes the plastic instead of crushing the structure itself.

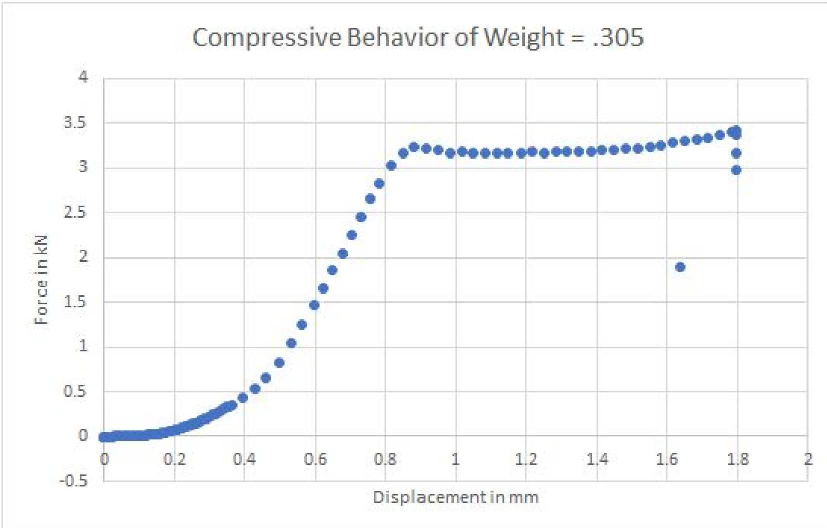
Samples of 30,40, and 50% will be tested likewise, and the results for the specimen with 60% infill is shown below, with the ‘elbow’ like point indicating the compressive elastic limit. The elastic limit as shown will be ‘xbar’ in the pooled variance t test to be ran. The standard deviation will be calculated as the average of the square root of the differences of each infill percentage from their respective averages.

Current Results



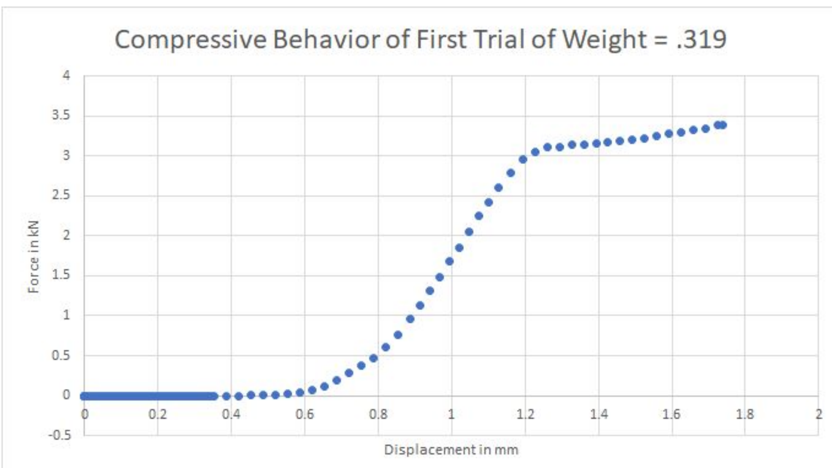
30% Infill:

Elastic Limit: 3.1839kN



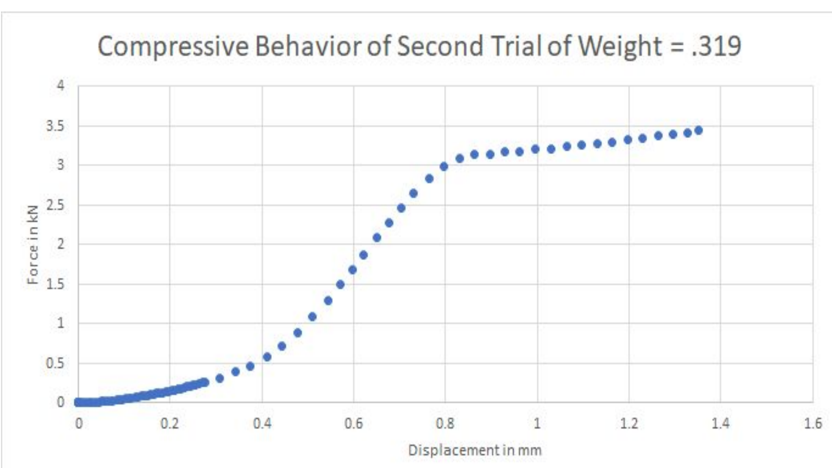
30% Infill:

Elastic Limit: 3.2282kN



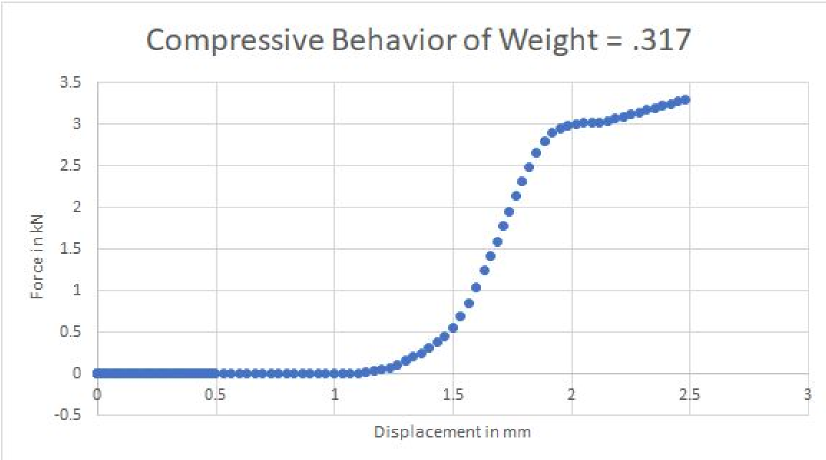
40% Infill:

Elastic Limit: 3.0488kN



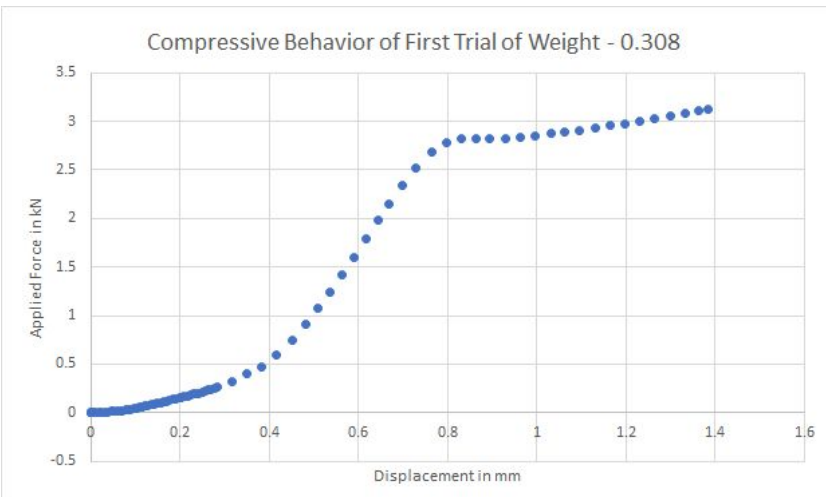
40% Infill:

Elastic Limit: 3.08725



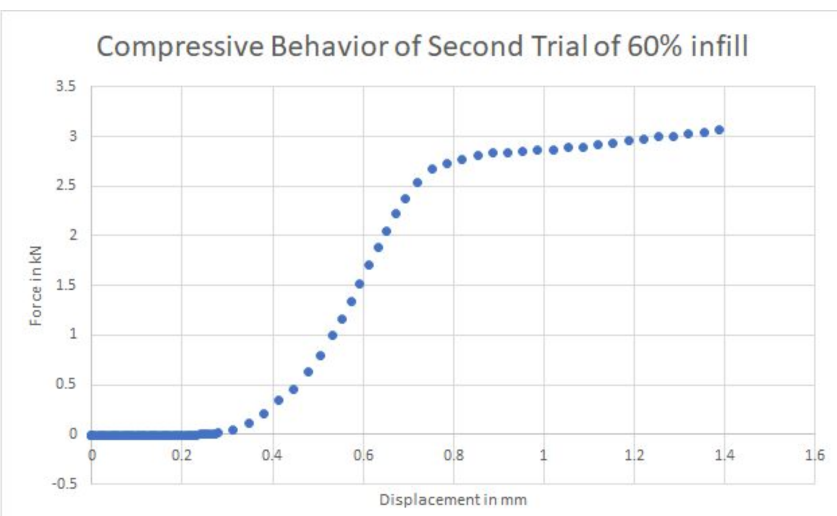
50% Infill:

Elastic Limit: 2.78121



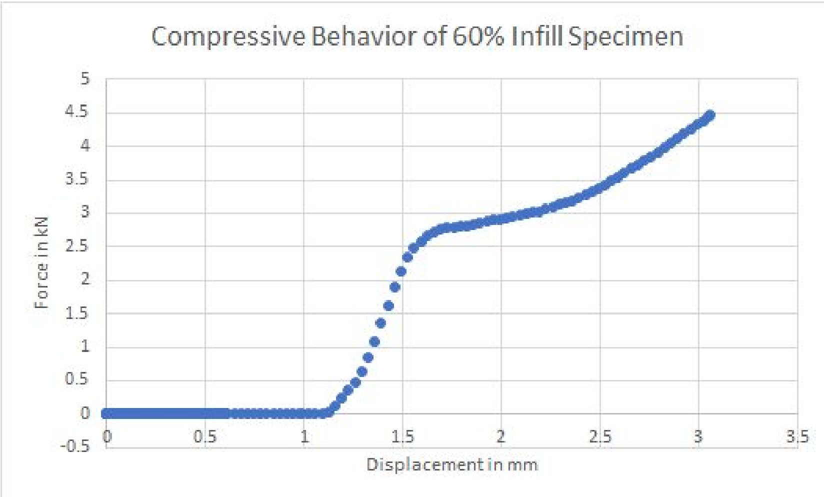
50% Infill:

Elastic Limit: 2.9785kN



60% Infill:

Elastic Limit: 2.7315kN



60% Infill:

Elastic Limit: 2.7248kN

References

[1] AMTA Strategic Priority Group on Music Therapy and ASD. (2015). FACT SHEET: Music Therapy and Autism Spectrum Disorder (ASD) [Pamphlet]

[2] Wilkins, A. (n.d.). Therapy at Dynamic Lynks. Retrieved from https://www.dynamiclynks.com/therapy

[3] Aguilera De Alba, L., Baye-Wallace, L., Dorf, A., Lederman, M., Lewis, R., Michaels, C., & Mowad, K. (n.d.). Djambe: Austism Music Therapy Drum Design Document [PDF]. Tempe: (Not Formally Published) EPICS at Arizona State University.

[4] Cain, P. (n.d.). Selecting the optimal shell and infill parameters for FDM 3D Printing. Retrieved from https://www.3dhubs.com/knowledge-base/selecting-optimal-shell-and-infill-parameters-fdm-3d-printing