Distributed Cyber Manufacturing Case Study

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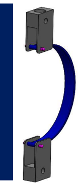

Introduction

What is Distributed Cyber Manufacturing?

Understanding the spread and shared technological information applied to manufacturing products.

How Case Study Began

- UNH and Portsmouth Naval Shipyard were tasks to create Covid-19 Face Shields
- Varying breaking points were observed from materials when headbands were printed on different 3D printers

Project Goal

To predict CAD model that reproduces consistent results across multiple 3D printers.

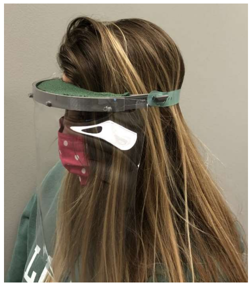

Figure 1: Portsmouth Naval Shipyard & UNH Covid-19 face shield

Methodology

- Materials: ABS and PLA
- SolidWorks Models
  - Simplified Headband
  - Corresponding Fixture
- SolidWorks Simulations
  - Force vs. Displacement plots: 20-140mm (20mm increments)
  - Fixture Static Analysis
- Zwick Machine
  - Tensile Testing: Obtain Poisson's Ratio & Young's Modulus
  - Compression Testing: Obtain Force vs. Displacement Curve
- Analytical Model
  - Predict Force vs. Displacement Curve and cross-sectional area of headband

Figure 2: Previous Covid-19 face shield Headband

Figure 3: Simplified Headband Design

SolidWorks Model & Simulation

- Headbands were displaced from 20mm to 140 mm at 20mm increments
- 20 Newton load on fixture analysis to ensure durability during Zwick Machine Testing

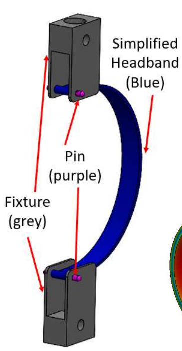

Figure 4: Fixture and Simplified Headband Assembly

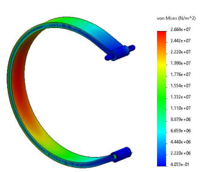

Figure 5: PLA 5mm Thickness Headband displaced 80mm. Resultant Force: 14.3 N

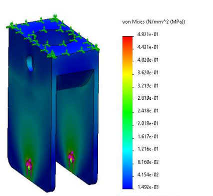

Figure 6: Stress Analysis on 3D printed Fixture - Maximum Stress: 4.82e-01 MPA Minimum Stress: 1.49e-03 MPa

Analytical Model

<u>Purpose</u>

- Predict the resultant force on the headband
- Provide a force vs. Displacement curve for each material at any given deformation

<u>Analytical Model Nomenclature</u>

- E = Modulus of Elasticity
- T = Correlation factor
- R = Radius
- C = Central Axis
- W = Width
- t = Thickness
- e = eccentricity

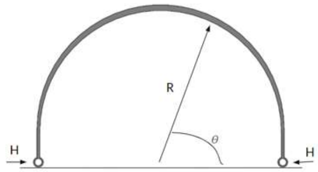

Figure 7: Diagram of headband including variable locations

$$F = \frac{\delta E t^3 w}{4c^3} - \frac{4c + \pi R}{2Etw} + \frac{\pi R}{4Etw} + \frac{Tc}{Gtw} + \frac{\pi RT}{4Gtw} + c\left[\frac{2R + \pi c}{2Etwe}\right]$$

Equation 1: Final force equation in analytical model

Testing setup

- Zwick Machine
  - Tensile Testing
    - 1000 N Load Cell
    - 5mm per min
  - Compression Testing
    - 100 N Load Cell
    - 15mm per min
- Digital Image Correlation
  - Acquisition rate – 1picture/250ms

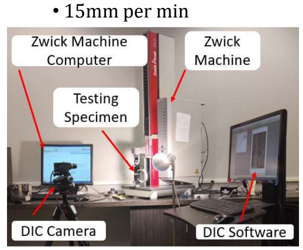

Figure 8: Experimental Setup of Compression Testing

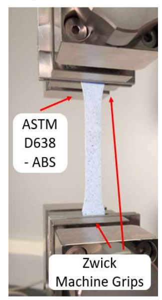

Figure 9: ASTM D368 Specimen in Zwick machine for tensile testing

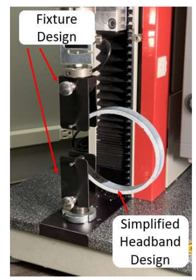

Figure 10: Headband and Fixture in Zwick Machine for compression testing

Tensile Test Results

- Difference between Prusa ABS and Kingsbury ABS material properties
  - Poisson's Ratio: 38% difference
  - Young's Modulus: 49% difference
- Material properties are inputted into analytical model and FEA analysis to create force vs. displacement curves

Table 1: Material, 3D printer and material properties obtained from tensile testing

Material	3D Printer	Poisson's Ratio	Young's Modulus (MPa)
ABS	Prusa	0.4166	2120.3
ABS	Kingsbury S221	0.2567	1076.9
PLA	Prusa	0.3996	1917

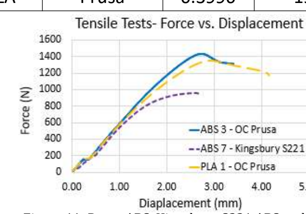

Figure 11: Prusa ABS, Kingsbury S221 ABS and Prusa PLA force vs. displacement curves

Analytical Model, Simulation and Compression Test Comparison

ABS Headband: Force vs. Displacement

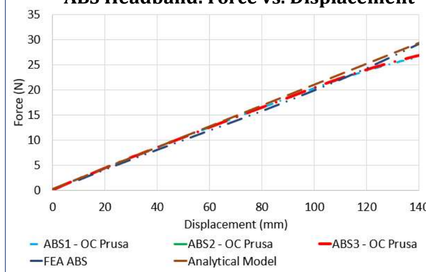

Figure 12: ABS Headband Force vs. Displacement with all compression tests

ABS Results

- Experimental, analytical and simulation data shows consistency in results.
- Can conclude that assumptions and models were accurate through experimentation.

PLA Headband: Force vs. Displacement

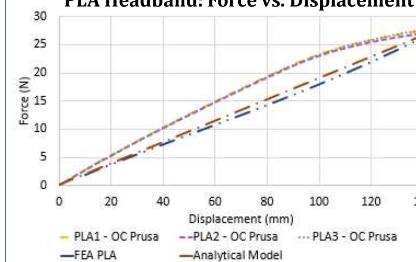

Figure 13: PLA Headband Force vs. Displacement with all compression tests

PLA Results

- Shows precision with the 3 tested samples
- Results of experimental data are slightly higher than estimated through simulation and analytical model.

Future steps

- Zwick Machine Testing
  - Complete tensile and compression testing for PETG and ASA
- 3D Printing
  - Understand what material properties vary when using different 3D printers
- Analytical Model
  - Optimize the geometry of the cross section of the headband to fit tighter to Force vs. Displacement curves
  - Incorporate the non-linearity experienced at the end of the test

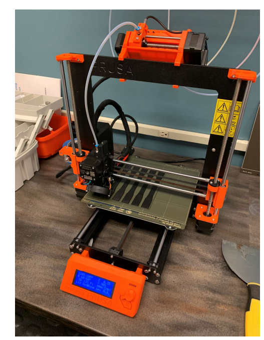

Figure 11: Prusa 3D printer in Olson Center printing tensile test specimens

Acknowledgements

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