Design of Controllable Stiffness Element for Dynamic Postural Brace

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Introduction

According to the Federal Bureau of Labor Statistics, the back injuries of more than 1 million workers account for nearly 20% of all injuries and illnesses in the workplace.

It has been proven that maintaining proper posture throughout the day can reduce work related back injuries. However, the major drawback of most postural back braces is the discomfort of wearing them for long periods of time, this leads users to incorrectly adjust the brace prioritizing comfort over function and leading to continued back injuries.

The purpose of this project is to develop variable-stiffness elements for a postural back brace that will be comfortable and functional for extended usage to help reduce work related back injuries.

Figure 1: Back injuries caused by repeating tasks in the workplace

Design 1: Origami Structure

An approach that increases stiffness by creating more distance from the neutral axis of the brace, therefore increasing the second moment of inertia.

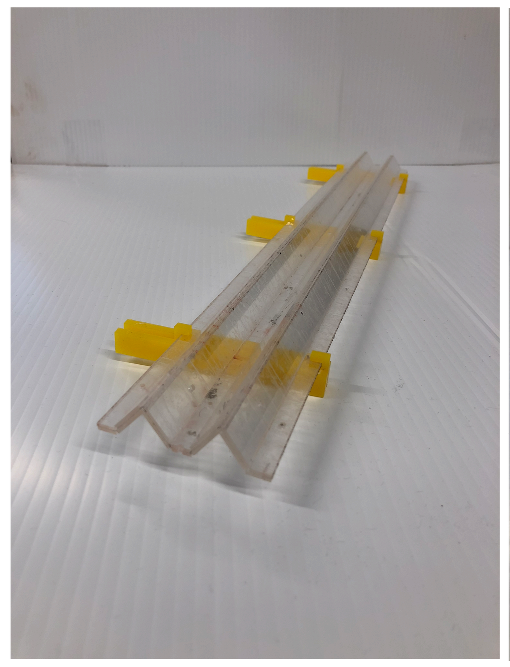

Figure 2: Corrugated

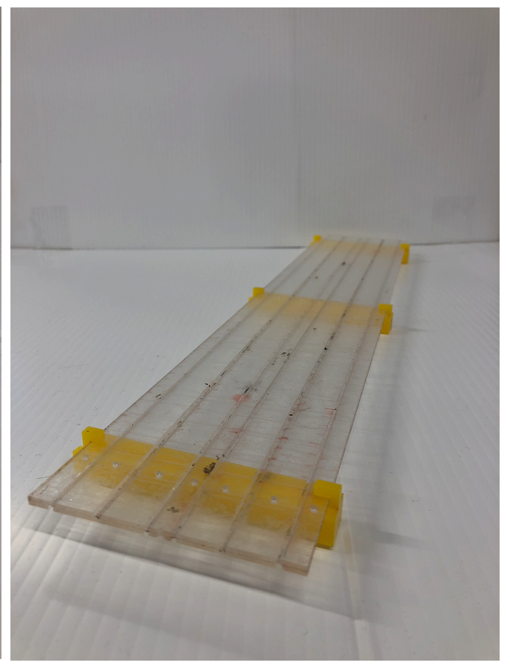

Figure 3: Flat

Design1: Results

$k = Stiffness$ $h = Height$
$I = Second\ moment\ of\ area$ $E = Bending\ modulus$
$b = Base$ $L_{eff} = Effective\ length$

$$k = \frac{48EI}{L_{eff}^3} \qquad I_c = (2n)\left(\frac{b^3h}{24} - \frac{\cos(2\theta)\left(\frac{b^3h - bh^3}{12}\right)}{2} + \frac{b^3h}{24}\right) \qquad I_f = (2n)\frac{bh^3}{12}$$

$$\boxed{\text{Stiffness ratio: } \frac{k_C}{k_F} = \frac{I_C}{I_F} = 50.5}$$

Figure 4: Origami Structure Equation Set

<u>Positives</u>:
+Lightweight
+Low energy
+Requires simple electric motors for actuation

<u>Negatives</u>:
-External control, such as motorized clamps or string tendons.
-Does not conform to the curvature of the spine
-Lower force resistance
-Lower stiffness ratio

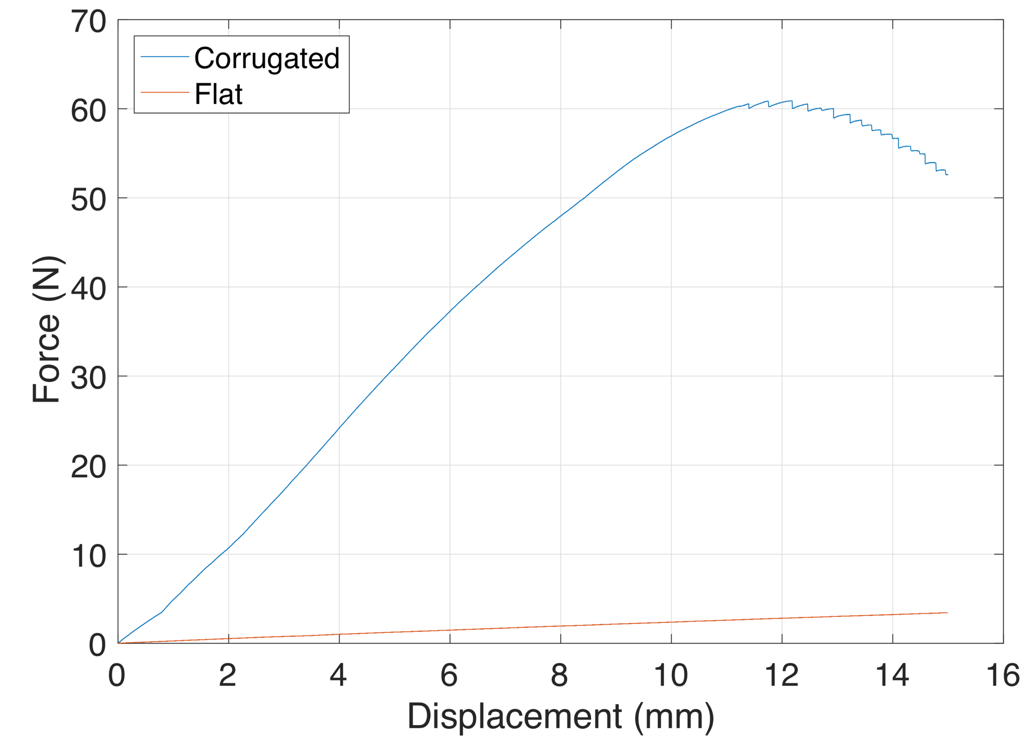

Figure 5: Origami Structure 3-Point Bending Test

Design 2: Layer Jamming

Multiple layers of a flexible material (in this case paper) are installed in an airtight bag. When vacuum is applied, the friction force between the layers increases, which causes the bending stiffness to increase.

Figure 6: Vacuum applied

Figure 7: No vacuum applied

Design 2: Results

$$I_1 = \frac{bnh^3}{12} \qquad I_2 = \frac{b(nh)^3}{12}$$

$$\boxed{\text{Stiffness ratio: } \frac{I_2}{I_1} = 10,000}$$

Figure 8: Layer Jamming Structure Equation Set

<u>Positives</u>:
+Conforms to the curvature of the spine
+Higher force resistance
+Higher stiffness ratio

<u>Negatives</u>:
-Requires a power-intensive pump which adds additional weight.
-Time delay in vacuum-packing

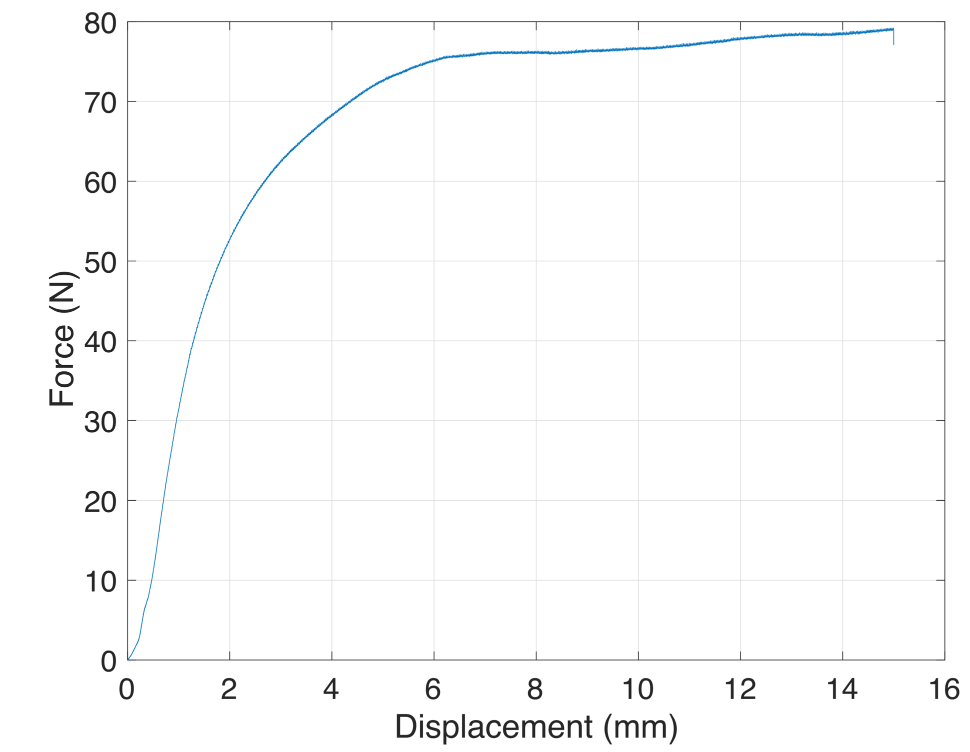

Figure 9: Layer Jamming 3-Point Bending Test

Conclusion/Future Works

The stiffness ratio compares the rigidity to the flexibility of the material, where a high ratio indicates there is a larger difference between the two. Ideally a high stiffness ratio produces a more dynamic brace, therefore future work includes fabrication of a layer jammed structure embedded into a shirt to maximize comfort and function.

Acknowledgments/References

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RIVeR lab
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