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Drop Tower Impact Tester For Auxetic Materials

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Problem Description

Auxetic materials have shown promising theoretical results in high impact absorption compared to conventional materials due to their unique geometry, as seen in Fig. 1 [1]. Auxetics can be useful in protective equipment such as sports helmets to reduce the likelihood of concussions [1]. Experimental validation of auxetic material is lacking because the University of Guelph does not have a suitable impact tester, and purchasing one is not feasible as they are too expensive and overly advanced. For this reason, a drop tower impact tester has been developed to further validate these theoretical results at a low cost.

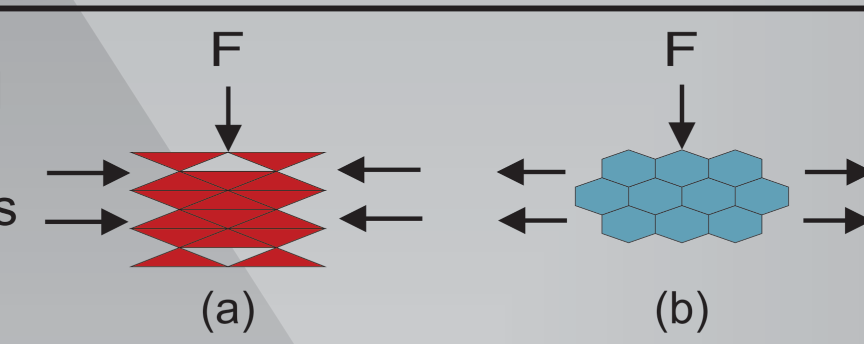

Figure 1. (a) auxetic v. (b) honeycomb structure under compressive load F.

Objectives

Design a cost-effective drop tower impact tester that is applicable for, but not limited to, testing auxetic materials; such that it adheres to the constraints listed:

- Tests must be initiable from a safe distance
- Structure 50X weight of specimen (ASTM D1596)
- Must raise drop platen to desired height (2m)
- Machine must be enclosed
- Must produce at least 200 J of impact energy to be comparable to commercial units
- Must be made from material with infinite life cycle

Design Solution

Overview

- Drop mass bolted to four high-speed linear bearings to reduce the likelihood of binding upon impact and disperse the overall shear force on an individual mounting fastener
- Drop platen raised/lowered using a 12V, 50kg electromagnet attached to DC electric winch with 1500lb capacity
- Laser cut top and bottom mounting faces ensure alignment of linear motion components with test specimen
- Test specimen placed on top of a force transducer - a 2" diameter steel dowel with strain gauges adhered to surface
- Strain gauge amplifier data is processed using an oscilloscope, exported as .csv
- Determination of energy absorbed by the material described in Fig. 3

Specifications

- Top and bottom, 3/8" HR steel mounting plates laser cut and welded to 84" long, 4" x 4" square tube
- The structure is braced using 2" x 2" HR square tube in 45-degree truss formations at the top and bottom of the device to reduce bending stress in the vertical column and end plates
- ¾" Linear guide rails mounted to top and bottom plates using 6061 aluminum flange mounts with a clamping screw
- Drop carriage is comprised of a solid 3" x 4" x 12" piece of steel (20kg)

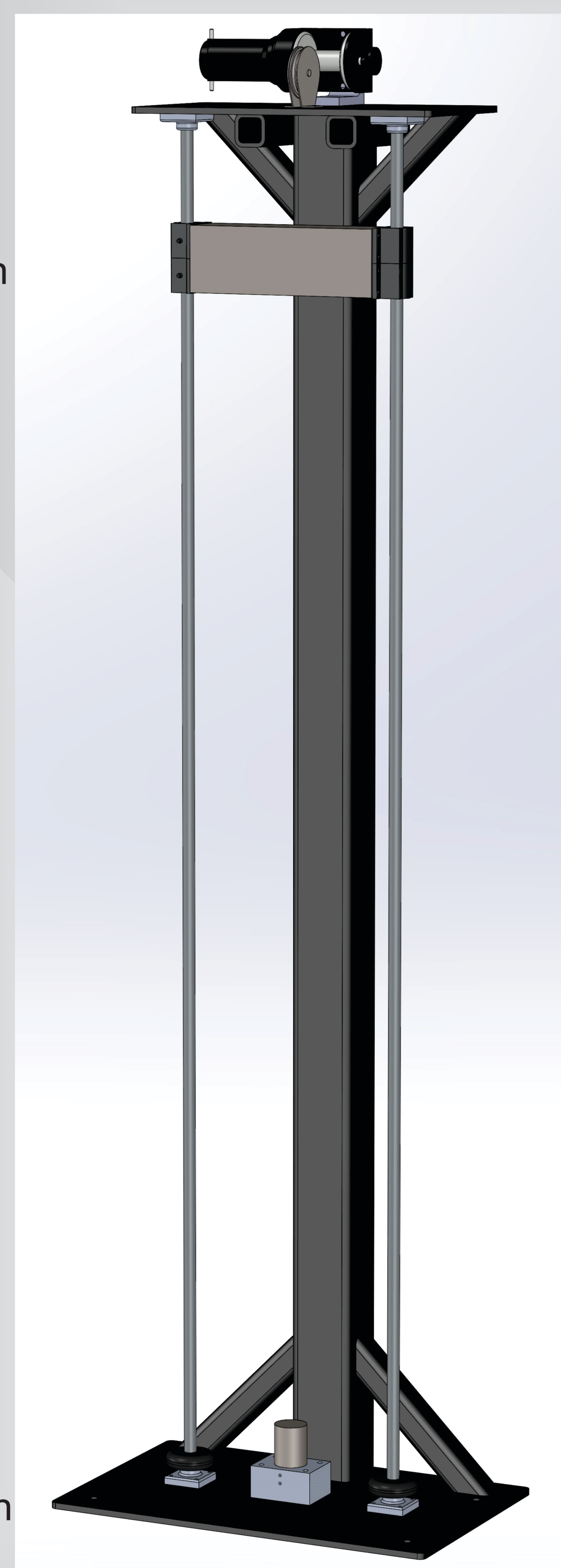

Figure 2. Isometric view of SolidWorks model of the drop tower impact tester.

Data Collection

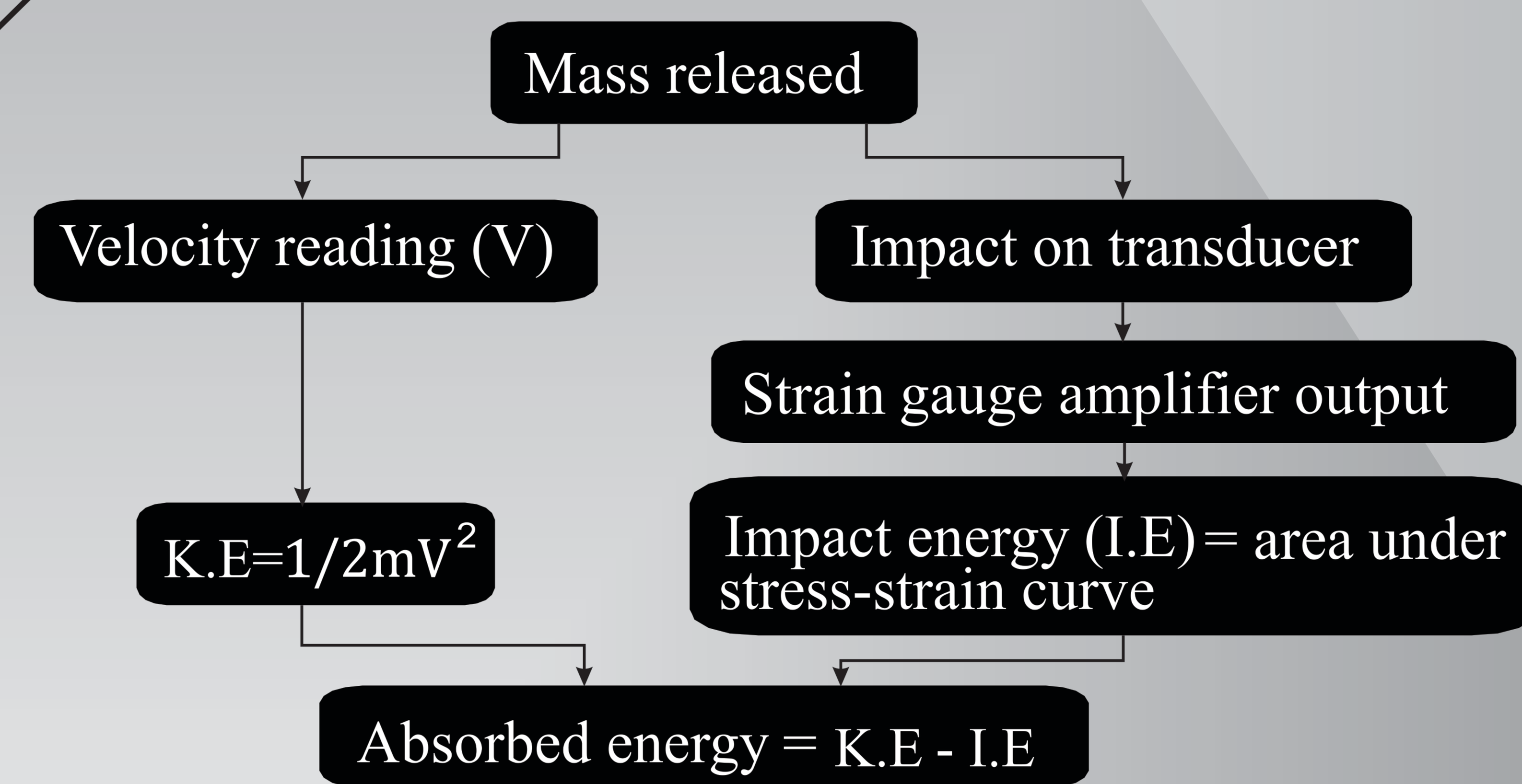

Figure 3. Flow chart describing the data collection process of the drop tower impact tester from when the drop platen is released to when the energy absorbed by the test specimen is calculated.

Structural Analysis

A static loading of 20kg case was simulated using finite element analysis in ANSYS. The von-Mises stress and deformation caused when the 20kg drop mass is raised to the top of the structure was evaluated.

- max deformation of 115 microns occurred at the tips of the top end plate (Fig. 4(a))
- max equivalent stress of 7.61MPa also occurred at the top plate (Fig. 4(b))
- The yield stress of the 1020 steel is 206 Mpa, resulting in a factor of safety of approximately 27.

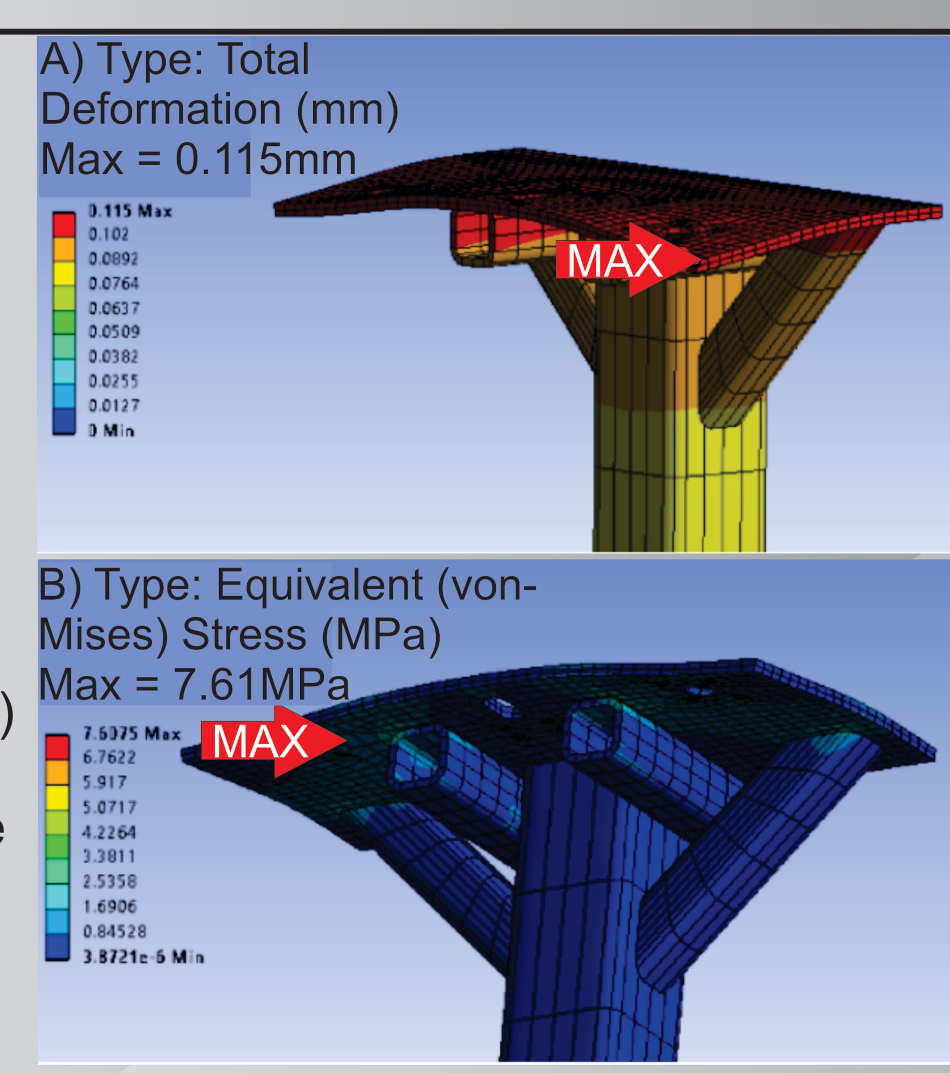

Figure 4. Finite element analysis of drop tower impact tester with 20kg static loading for (a) max deformation and (b) equivalent stress.

Conclusion

Overall, this drop tower impact tester will provide a cost-effective solution for researchers at the University of Guelph to determine impact properties of various materials such as Auxetics, composites and additive manufactured geometries. The design is scalable for future iterations that may require greater impact energy or additional test space.

Acknowledgement and References

Acknowledgement. Thank you to our advisor Dr. Hari Simha for his guidance and expertise, and to Restoration Design for assistance with laser cutting.

[1] Montenigro P. H., Alosco, M. L., Martin B. M., Daaneshvar D. H., Mez J., Chaisson C. E. (2017). Cumulative Head Impact Exposure Predicts Later-Life Depression, Apathy, Executive Dysfunction, and Cognitive Impairment in Former High School and College Football Players. Journal of Neurotrauma, Vol. 34, No. 2.

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