

2020 LSMRCE Annual Conference

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A virtual event
November 6-7, 2020



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Louis Stokes Midwest Regional Center of Excellence is supported by National Science Foundation award numbers HRD-1826626 (IUPUI) and HRD-1826719 (CSU)(2018-2023)

People's Choice Poster Winner

Bioinspired Horse Hoof Models for Impact Resistant Materials

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Bioinspired Horse Hoof Models for Impact Resistant Materials

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Background
Bioinspiration is the utilization of biological materials as blueprints for new, synthetic materials. Optimized through a millennia of evolution, the horse hoof is the subject for creating bioinspired high impact resistant materials.

Motivation
Horses are heavy creatures that impact the ground at high speeds, making their hooves specialized to protect interior flesh. Studying hooves can lead to creating better impact resistant materials. Impact resistance means having the ability to absorb high amounts of energy or shock and thus be less likely to break or deform. Impact resistance can address the need for materials in applications such as helmets, personal protective equipment, car trumpe, and aerospace applications.

Objective
To design bioinspired models with two aims:
1. Learn more about functionality of hoof microstructures
2. Create guidelines for future bioinspired models and impact resistant materials

Method
Gather data on dimensions of tubular microstructures from previous studies
Scale up dimensions from microns to macrovals
Use data to model samples using Computer Aided Design software
3D Print the models
Conduct physical impact and compression testing on the models
Analyze results to make comparisons with models and real hoof samples

Results
Models 1-3: Single material
Models 4-6: Multiple materials
Models 7-8: Layered 3 prints
Physical 3D printed models were printed using PolyJet method as 300µm resolution samples. Print materials are ultraclear, clearClear (E+G GPa), Rigid (E+1.2 GPa), ToughBlack (E = 0.9 MPa) to recreate similar ratios seen within the real hoof wall samples.
Preliminary Results for Physical Testing
Initial drop tower impacting testing results are promising. As predicted, the tubules do show visual signs of crack deflection behavior similar to the behavior seen in the real hoof. In Figure 8, green circles indicate tubules that helped to guide/deflect the cracks. Red circles indicate tubules where the crack interface is actually arrested by the tubule.
Both crack deflection mechanisms are also present in the real hoof, validating these synthetic models to the extent of this initial testing. After seeing this proof of concept, testing is continuing.

Discussion
In testing phase, the models have shown great promise in results. Expected results from the physical tests will provide insight on how the models behave which can lead to greater understanding of the functionality of the tubular structure. With these results, comparisons can be made with previous results from studies done on real hoof samples. When comparing mechanical performance, it is expected that the bioinspired models would outperform the actual hoof samples because of the improved mechanical properties of the synthetic materials. Through this general comparison, the design of the bioinspired models can be validated.
Future work includes exploring:
• Different scale and number of tubules (a single tubule or an arrangement of four tubules) (as seen in Figure 9)
• Finite element analysis and simulations for the models (as seen in Figure 10)
• Hooves of other species

Conclusion
As an ongoing research project, the bioinspired models are soon to be characterized and validated. The models have the potential to make a strong contribution to both bioinspiration and the study of the horse hoof. This project, as an intersection point of materials science, biology, and mechanical engineering, will help to catalogue property findings and culture design guidelines for new synthetic materials. The study of the microstructure of the horse hoof through model design will provide novel insights on the burgeoning field of bioinspiration and will contribute to the next generation of impact resistant materials.

Acknowledgements
Work supported by National Science Foundation grant 1905161, Special thanks to mentors Ben Lazarus, Dr. Marc Meyers and the Louis Stokes Midwest Regional Center of Excellence.

References



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