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Beetle Elytron-Inspired Structures for Enhanced Impact Resistance in Aircraft and Automotive Shell Components

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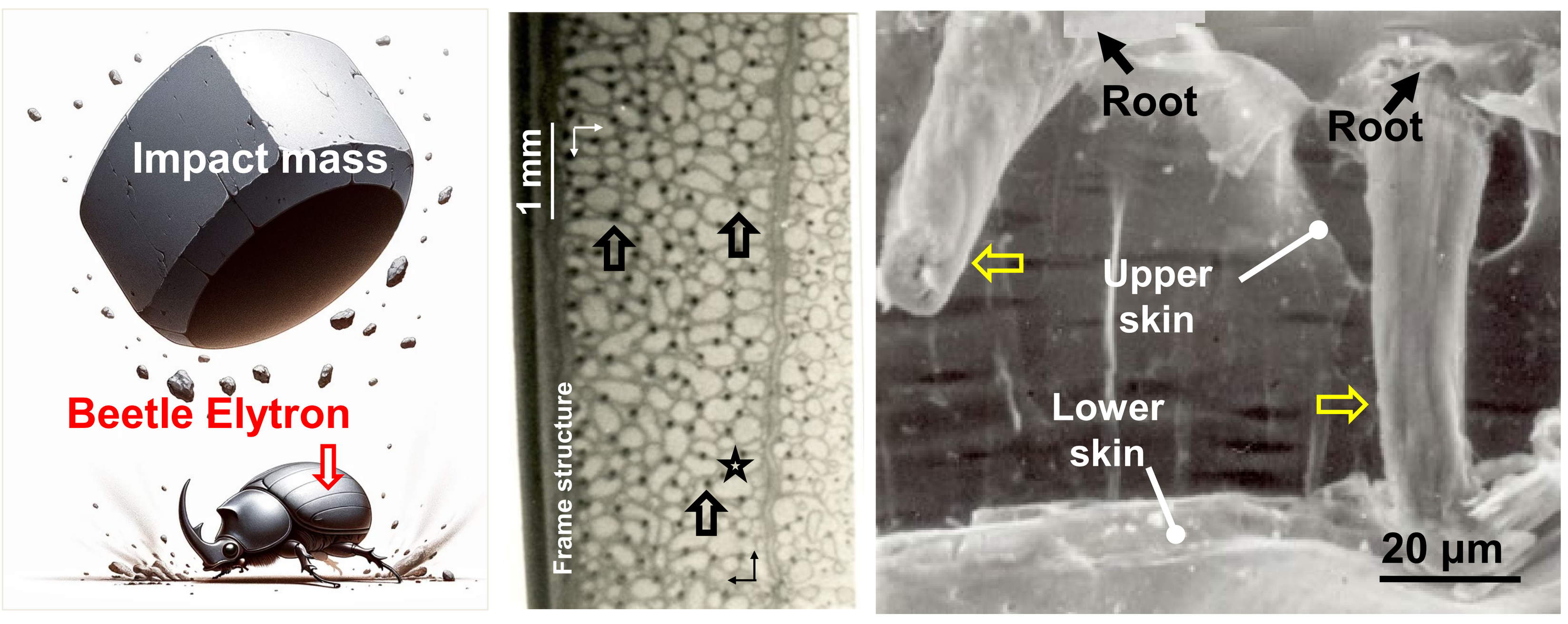
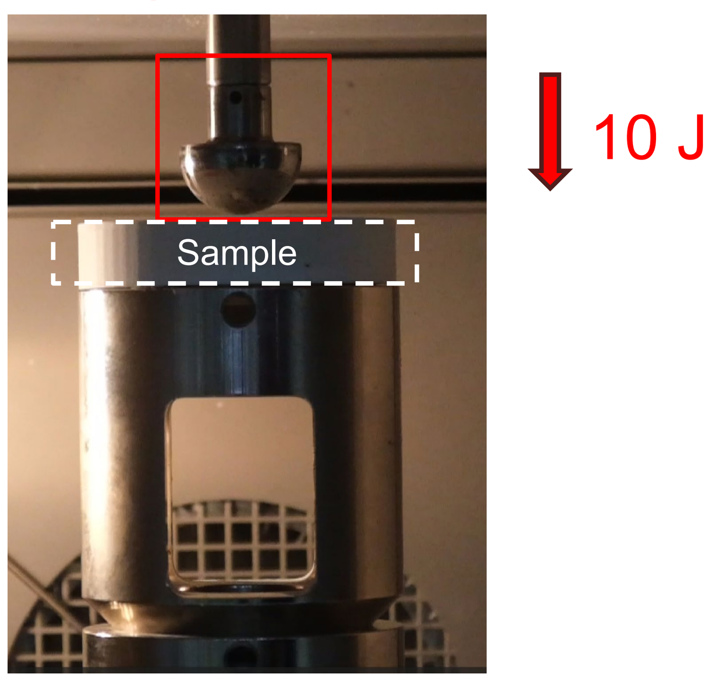
INTRODUCTION & AIM

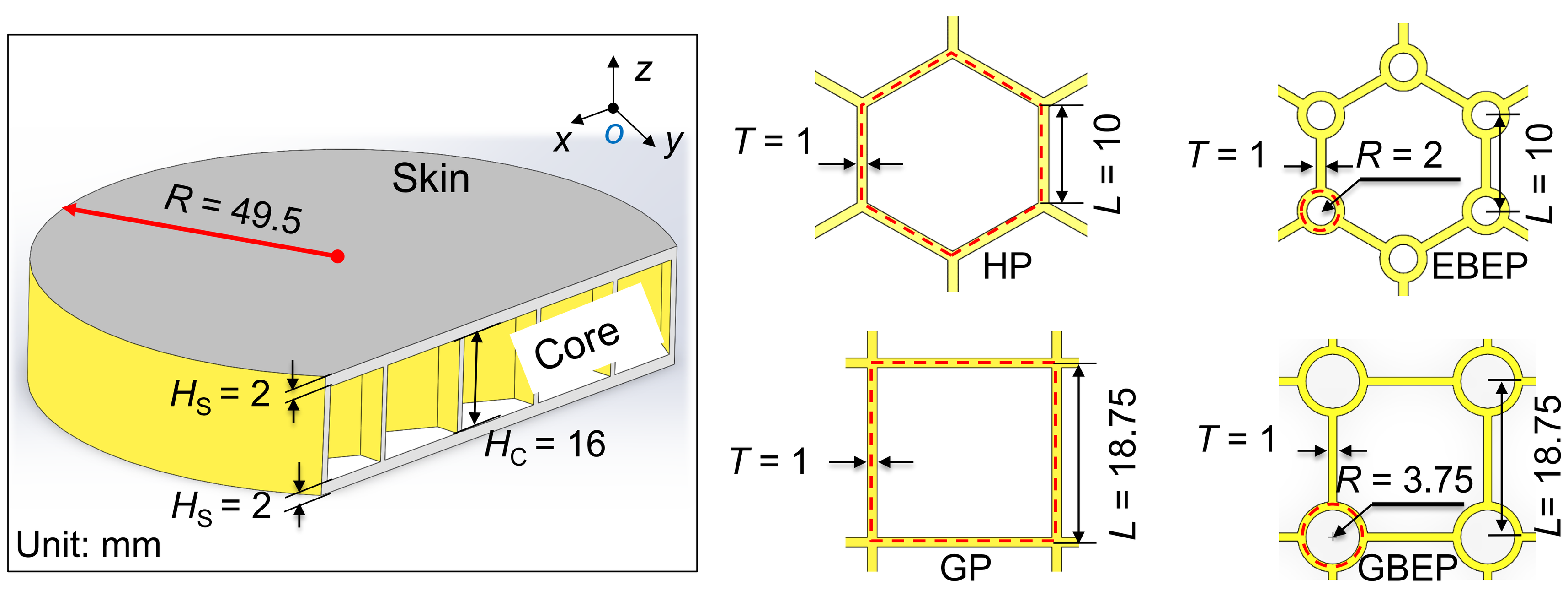
In aerospace and automotive engineering, improving impact resistance while maintaining lightweight structures is critical, particularly for shell components. Bio-inspired beetle elytron plates (BEPs) offer promising solutions due to their natural design, providing enhanced mechanical performance under impact conditions.



METHOD

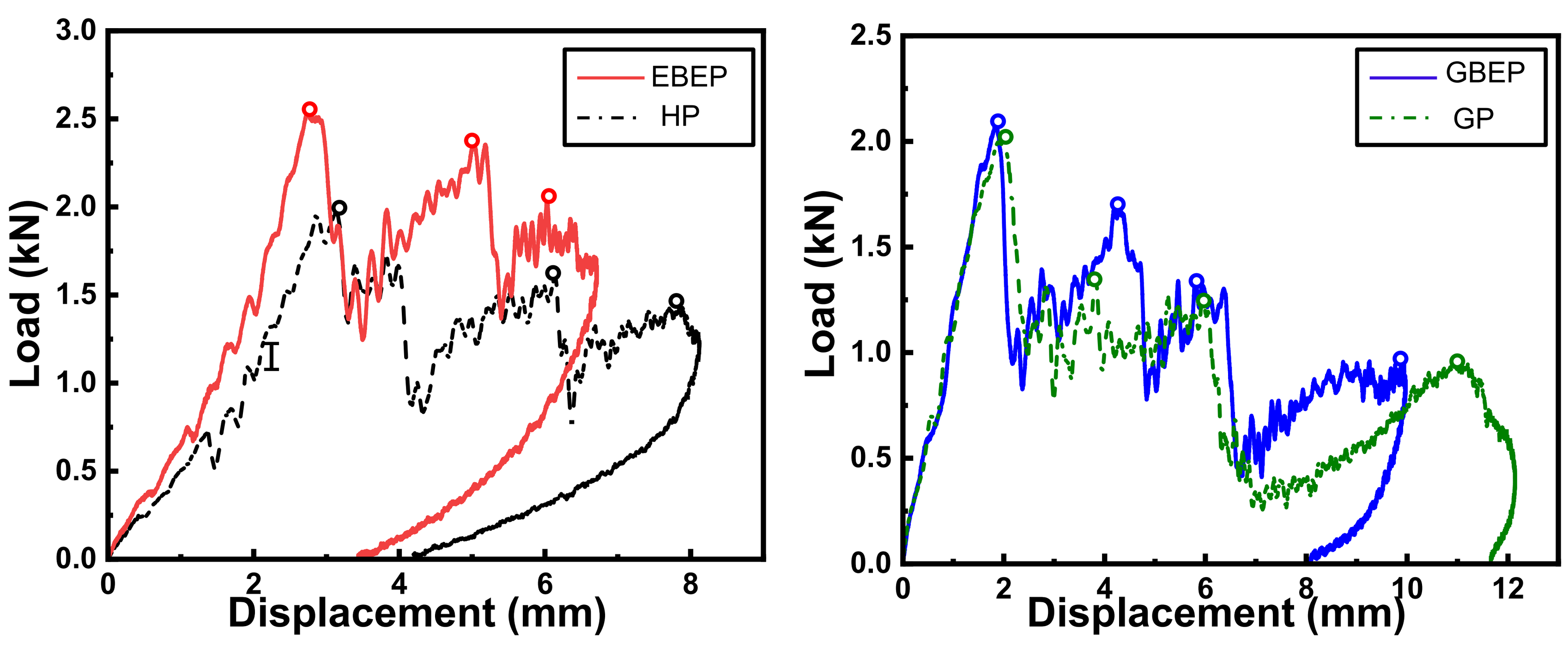
This study focuses on end-trabecular beetle elytron plates (EBEPs) and grid beetle elytron plates (GBEPs) fabricated through additive manufacturing using eco-friendly materials. These plates were compared to conventional honeycomb plates (HPs) and grid plates (GPs) under 10 J impact energy. Dynamic impact tests were conducted using a drop hammer system to measure key performance indicators such as peak force, specific energy absorption (SEA).





RESULTS & DISCUSSION

The results show that EBEP and GBEP plates exhibit enhanced performance compared to conventional plates, with notable improvements in energy absorption and reduced impact deformation. The bio-inspired designs resulted in energy absorption increases of approximately 7% to 10%, while deformation under impact was reduced by more than 5% in both cases. The trabecular structures within EBEP and GBEP facilitated better load distribution, leading to up to 15% more stable impact resistance and smaller deformation zones. Additionally, both plates demonstrated higher mean force retention, exceeding that of conventional plates by around 12%, and exhibited greater structural integrity under repeated impacts, underscoring the effectiveness of the bio-inspired designs in mitigating damage through optimized stress dispersion.



CONCLUSION

The findings highlight the potential of bio-inspired beetle elytron plates for enhancing impact resistance in aerospace and automotive shell components. The trabecular structures in EBEP and GBEP effectively reduce localized damage and improve energy absorption, making them strong candidates for advanced engineering applications where lightweight design and high impact resistance are essential. The research group of this work has already developed the methods and experience to design and fabricate curved beetle elytron plates, and future studies will focus on low-velocity impact tests to further meet the demands of lightweight, high-strength components and structures in aerospace and mechanical applications.