Performance of fish scale-inspired armor under impact loading by different impactor shapes – A numerical investigation

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INTRODUCTION & AIM

This paper investigates the performance of fish scale-inspired protective structures under the impact loading by different impactor shapes. A composite scale-tissue model was designed by replicating the complex hierarchical architecture of the elasmoid fish scale. The natural design of the fish scale has a varying overlapping angle depending on the location of these scales (anterior, mid-section or posterior). Likewise, the thickness of these scales varies from species to species and within the different locations of the body. Inspired by these elasmoid fish scales, the curved elliptical fish scales were designed [1]. Studies have shown that the impactor shapes significantly influence the failure mechanisms and impact resistance behavior [2].

This study utilizes numerical methods to examine the impact resistance behavior. The fish-scale-inspired protective structure could enhance the impact resistance and further development of the body armor.

METHOD

Low-velocity impact scenarios were investigated using commercially available finite element analysis (FEA) software ANSYS LS-Dyna. The fish scale-inspired design measured a length of 19 mm, a width of 12 mm and an inclination of 10°. Total size of the specimen measured 80 mm × 80 mm × 10 mm. The acrylonitrile butadiene styrene (ABS) material represented the hard scales, while thermoplastic polyurethane (TPU) mimicked the soft tissue.

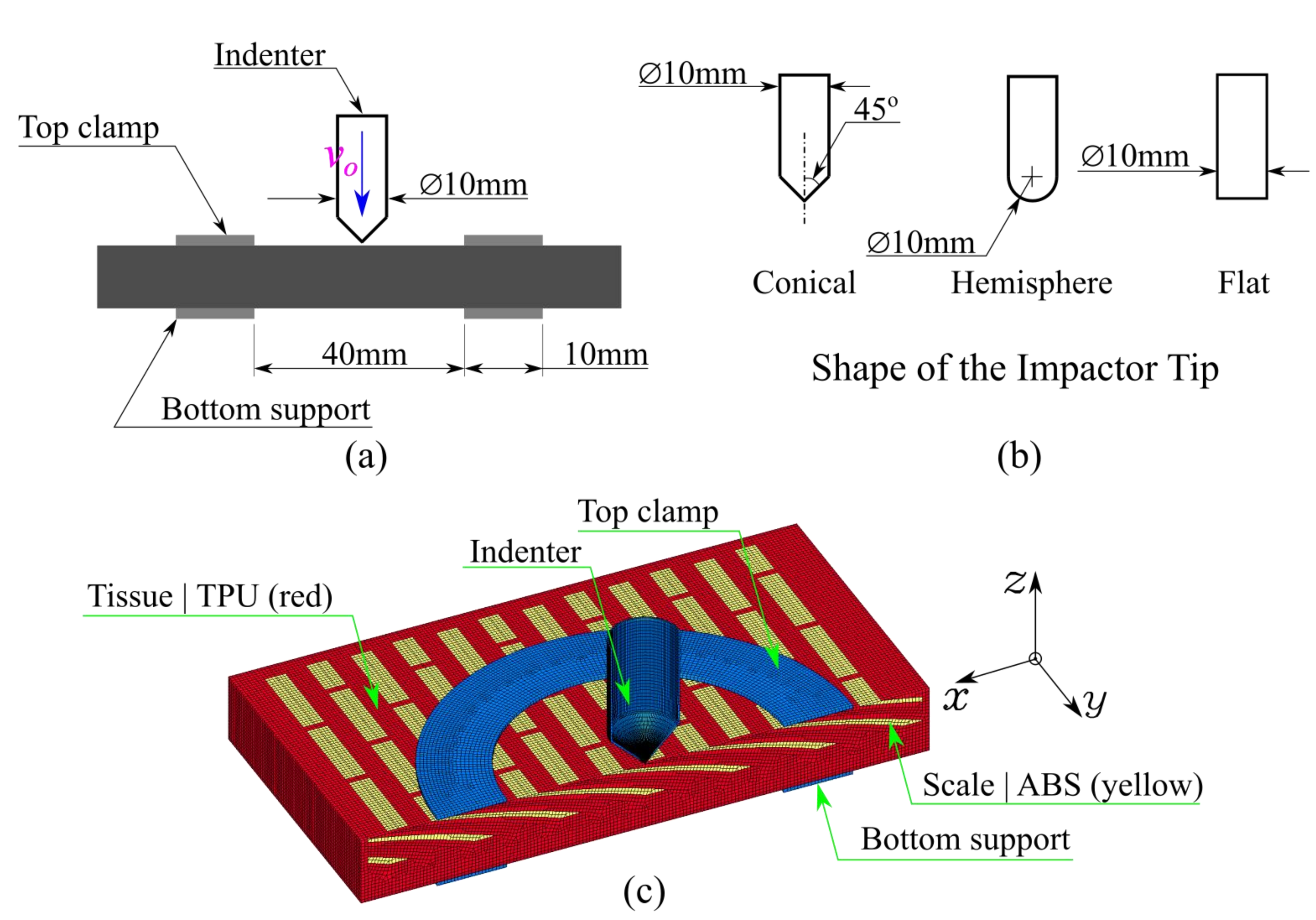

Fig 1. Geometry, physics, and FEA model of elasmoid fish scale-inspired design study

Scales/ABS were modelled using a plastic kinematic (MAT03) material model, while the tissue/TPU were modelled using plasticity polymer (MAT89). The effect of indenter shape (hemispherical, conical, and flat head) was studied at impact energy and velocity of 100 J and 6 m/s. The eroding surface-to-surface contact algorithm was defined between the impactor and the specimen.

RESULTS & DISCUSSION

Local stress distribution over the impact area was explored using FEA. Initiation of the back face cracks was observed early in the flat head indenter. The damage was highly localized for the conical indenter. The major failure mode of scales for conical impactor was breaking of scales and for flat head scale were large plastic deformation.

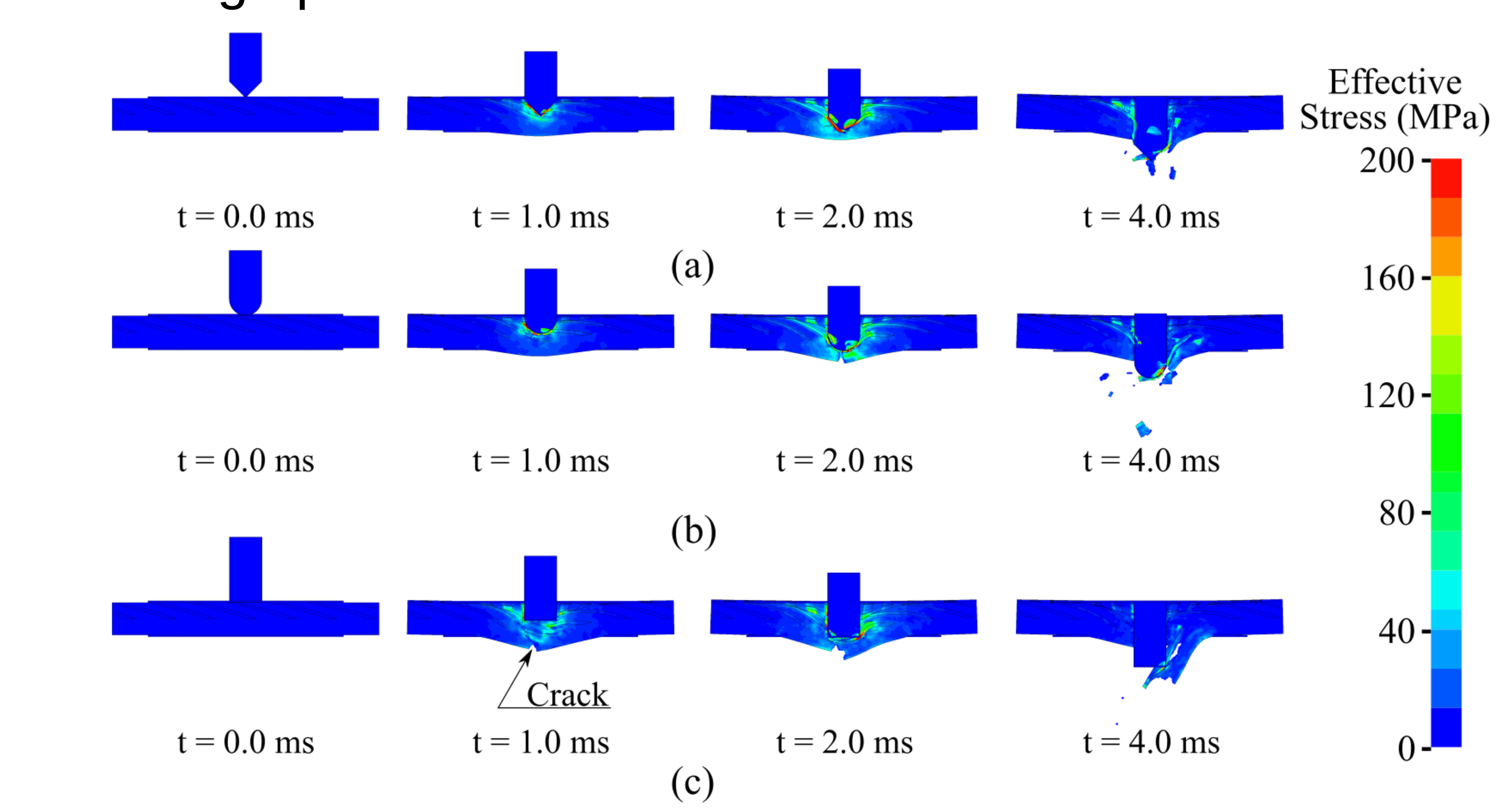

Fig 2. Puncture stress history at an impact energy of 100J by (a) Conical (b) Hemispherical and (c) Flat head impactor

The shape of the impactor had a substantial influence at lower energy levels. At an impact energy of 100J, the force histories for hemispherical and flat-head impactors were comparable. The influence of the indenter shape was lower at a higher strain rate loading.

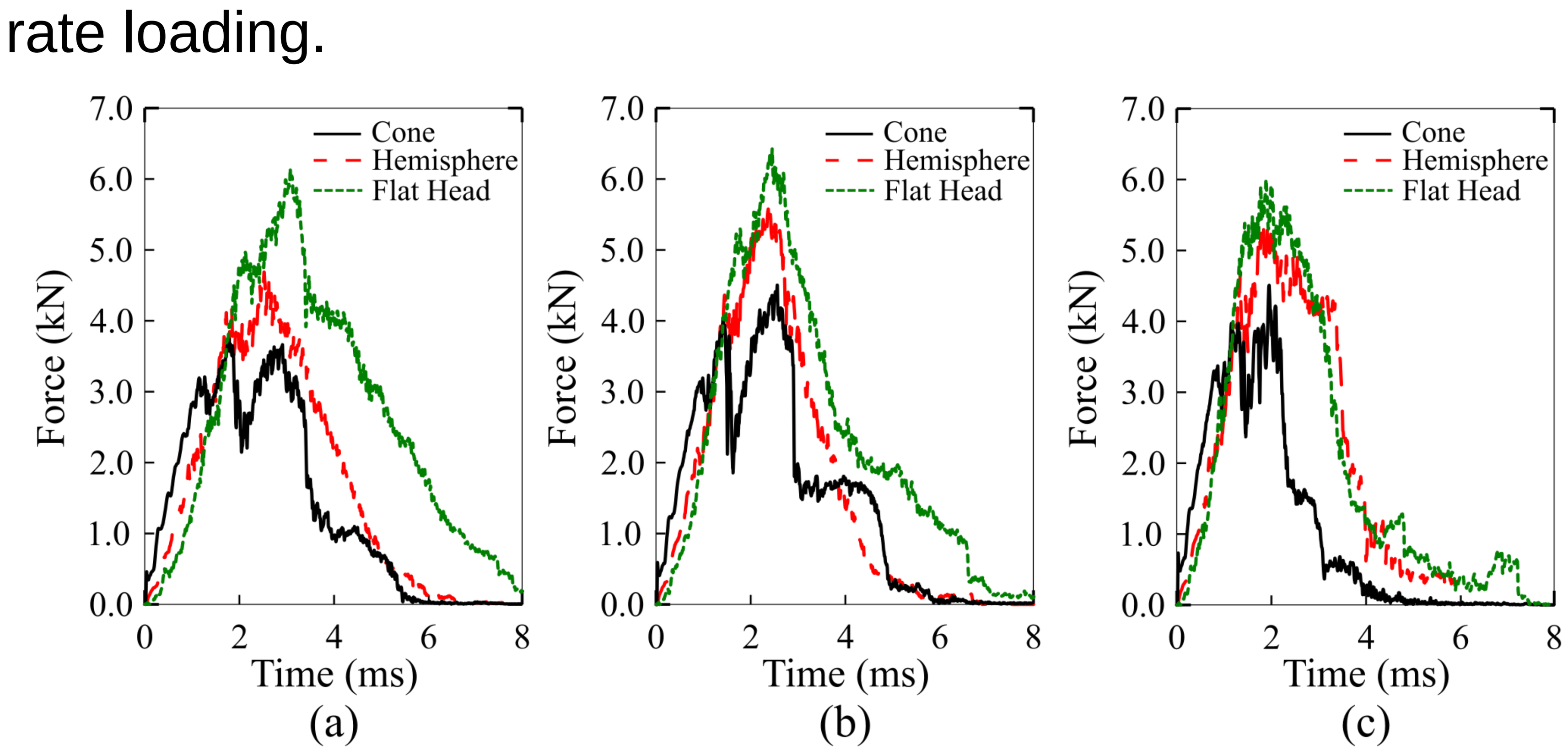

Fig 3. Puncture force history at an impact energy of (a) 50J (b) 75J and (c) 100J

CONCLUSION

- The structure exhibited maximum resistance to the flat-head impactor and minimum resistance to the conical impactor.
- The peak force absorbed by the hemispherical, conical, and flat head indenters at 100J impact energy was 6.1 kN, 5.4 kN and 4.5 kN, respectively.
- The earliest signs of fracture were observed when impacted with the flat-head impactor.

REFERENCES

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