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Fish Scale Inspired Stab Resistant Body Armour

Sidharath Sharma, Parvez Alam*
School of Engineering, University of Edinburgh, United Kingdom

INTRODUCTION & OBJECTIVES

The statistics from the House of Commons Library reported crimes involving a knife or sharp instrument saw a 9% year-on-year increase in the UK, with 45,000 offences recorded in March 2022. While commercially available lightweight stab-proof apparel exists, they offer little resistance to stabbing and are primarily designed to withstand slash attacks. In this study, we took inspiration from nature to prototype an armour design with the following objectives:

- Emulate the Home Office Scientific Development Branch (HOSDB) Body Armour Standard 2017 by developing a drop weight tower.
- Identify a bio-inspired structure for the development of lightweight and flexible body armour.
- Develop additively manufactured nylon samples to carry out detailed comparative study between the bio-inspired structure and flat plates.
- Test the samples at an angle of incidents of 45° and 90° to compare the different orientations of stab attacks
- Evaluate the failure modes and analyse the results.

METHODOLOGY

The design samples shown in Fig. 1 were inspired by overlapping fish scales, interlocked, allowing for a flexible and segmented design. Segmentation such as of the scales below had been studied to show advantages in repeated stab attacks. The test critical thickness of the scaled samples was calculated using a rapid prediction model by Yaxin Guo et al (2020) as 4mm for a test energy of 5 joules set by adjusting the drop height.

Fig. 1: Fish Scale armour sample

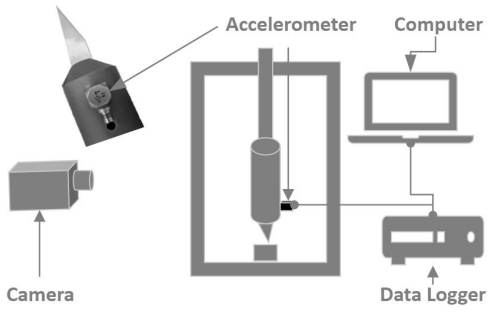

Fig. 2: Test Set-up

A bespoke drop weight tower was manufactured to carry out the tests and the data was recorded using an accelerometer and a high-speed camera to validate the results as shown in Fig. 2. Control samples (60mmx60mm) were additively manufactured and tested, with thicknesses ranging from 4mm – 8mm to carry out a comparative study.

RESULTS & DISCUSSION

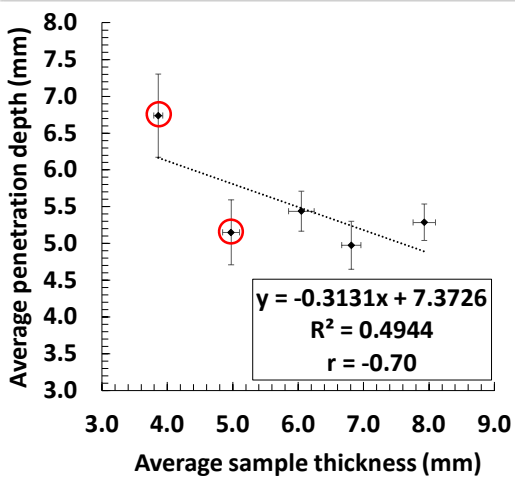

Fig. 3: Penetration depth against sample thickness

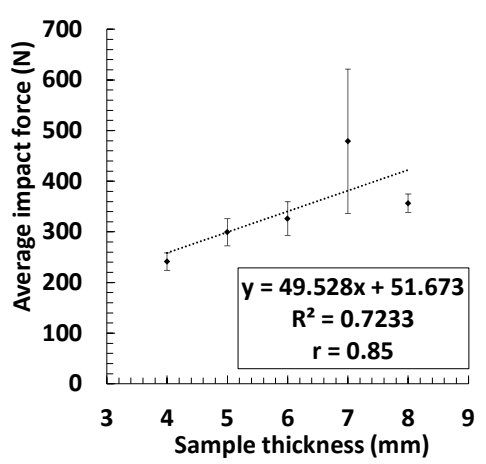

Fig. 4: Average impact force against sample thickness

As shown in Fig. 3 only the plate samples with thicknesses 4mm and 5mm were fully penetrated. A negative correlation was observed between the average penetration depth and the average sample thickness. Additionally, the fish scales at an orientation of 45° showed no penetration.

As shown in Fig. 4 there was a positive correlation between the sample thickness and the average impact force. This is because the stiffness of the sample increased with thickness as such it was unable to deflect, leading to the knife decelerating faster.

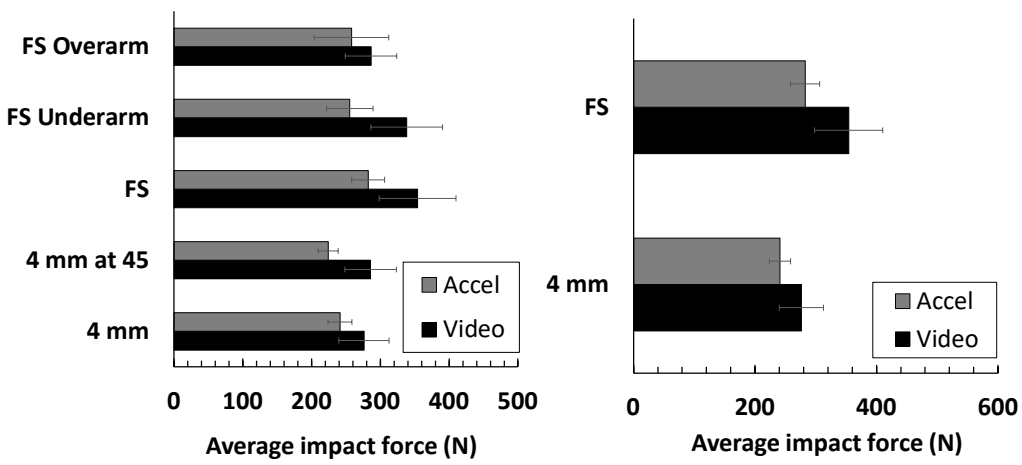

Fig. 5 Sample type against average impact force

As shown in Fig. 5 the average impact force was greater for the interlocked fish scales compared to the 4mm plate samples in general because the span-to-thickness ratio was smaller for the individual fish scales due to segmentation, making them stiffer.

CONCLUSION

We found that fish scales at 45° (overarm and underarm) showed no penetration (through the back of the scale) despite the scales being 4mm thick. This is because the resultant force had a normal and a transverse component that allowed the interlocks to engage and dissipate the energy.

REFERENCES

Yaxin Guo, Mengqi Yuan, Xinming Qian, Yuchen Wei, and Yi Liu. Rapid prediction of polymer stab resistance performance. Materials & Design, 192:108721, 2020.