Development of Sustainable PPE for Higher Threat Clearance Operations by Humanitarian Organisations

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Project Background

- In 2020, the Halo Trust reported that 59 countries and territories were still contaminated by landmines and other UXO.
- There is a need to create sustainable armour, whilst still offering increased protection against higher velocity fragmentation.
- Natural fibres have the potential to improve the performance of hard and multi-layered armour systems whilst also reducing weight and cost.

Overall Research Project Objectives

1. Understand the current level of protection attributed to current demining vests.
2. Investigate the ambiguities of IMAS 10:30.
3. Define survivability and common threats to determine whether PPE and PPE standards should be improved.
4. **Identify and test alternative soft and hard armours against higher velocity fragmentation threats.**

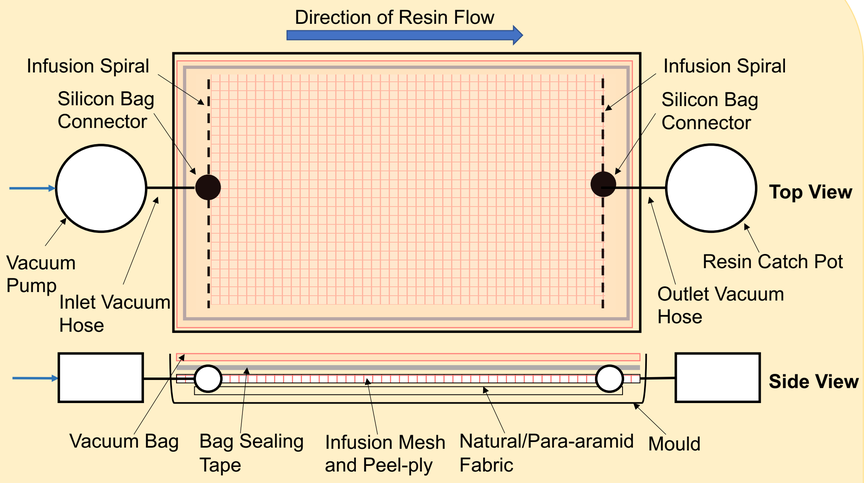
Testing Natural Fibres in Protective Hard Armour Panels

- **Aim:** This study compares the ballistic protection performance of hard armour panels that have been made from both traditional para-aramid fabrics against those that have been made using natural fabrics or a combination of both.
- The current standards states:

"PPE shall also be capable of protecting the chest, abdomen and groin area against the blast effects of 240gm of TNT at 60 cm from the closest part of the body, and also achieve a V50 rating (dry) of 450m/s for 1.102g fragments"

Manufacturing

- Panels were fabricated via Resin Infusion with both natural fabrics (Flax and Ramie) and Kevlar.
- Panels were either 100% of one material, or as a natural fibre Kevlar hybrid and were 130mm x 150mm.
- The hybrid panels utilised a 50/50, 75/25 or 25/75 split.

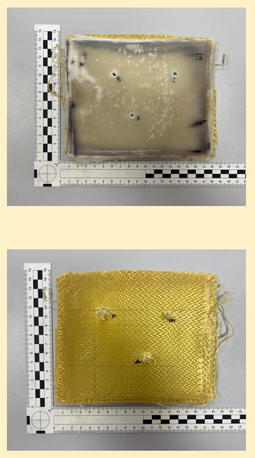


Schematic showing the production of a fabric epoxy resin composite hard armour panel via the process of resin infusion. Illustration created by the author.

Testing

- Ballistic testing was carried out on a gas gun at 40 bar pressure (V_{in} 357.5ms^{-1}) with 1.102g FSPs.
- Shots were 50mm (10x projectile calibre) from each other and filmed with a high-speed camera.
- Phantom Camera Control Software was used to confirm the V_{in} and V_{out} values.

Image of a panel set up within the capture area of the gas gun.



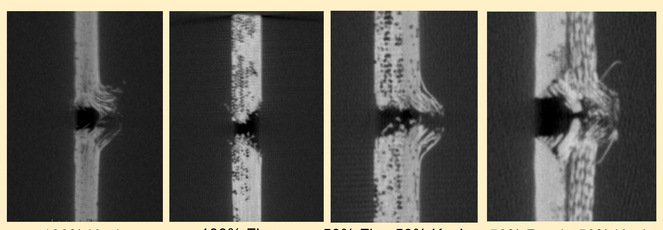
The front (top) and back (bottom) faces of the 20-layer Ramie, 10-layer Kevlar panel.

Analysis

- The 100% Kevlar panels performed best out of the three with 100% composition.
- However, the 50% Ramie 50% Kevlar panel performed best out of all the panels – average ΔV of 197.11ms^{-1}.
- These superior results may be due to the Ramie fragments "self-plugging" the holes and subsequently slowing the FSPs down.
- Post shot CT analysis also showed very interesting fracture behaviour.
- Small "prongs" can be seen protruding into the Kevlar.
- No clear correlation between the results of the tensile testing and ballistic testing.

Panel Materials	No of Layers	Average Mass (g)	Average Stress to Break (MPa)	Average ΔV (ms^{-1})	Rank
Kevlar	20	126.10	305.0	170.11	2
Ramie	40	185.61	68.0	123.67	7
Flax	16	202.95	53.3	148.22	6
Ramie/Kevlar	20/10	162.22	196.2	197.11	1
Flax/Kevlar	8/10	163.68	182.1	162.67	4
Flax/Kevlar	4/15	155.44	302.4	163.44	3
Flax/Kevlar	12/5	189.82	114.9	154.22	5

Table showing the results of the v_{in} and v_{out} testing performed on the hard panels



100% Kevlar | 100% Flax | 50% Flax 50% Kevlar | 50% Ramie 50% Kevlar

Comparison of post shot CT scans.

Conclusion

- Hybrid panels can be better than Kevlar panels at reducing the residual velocity of an FSP.
- The 50% Ramie 50% Kevlar panel produced a 15.9% higher reduction in velocity with only a 28.7% increase in mass.
- The replacement of Kevlar with natural fibres can also reduce the cost and environmental harm.
- Plugging was seen in the Ramie Kevlar panels and confirmed with CT scans. It is unknown if this influences the reduction of velocity.

Example of current PPE systems from The HALO Trust

Next Steps

- Explore the influence of fabric thickness and mass density on the results of the ballistic testing.
- Look at how the orientation and order of the layers of materials may influence the results – change the qualitied of Kevlar and Ramie.
- Test the Ramie Kevlar panel against different sized FSP's and different projectile velocities.

References

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