**AMBA – Additive Manufactured Body Armour**

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The development of knife-resistant flexible body armour to UK performance requirements utilising graphical generative algorithms and Additive Manufacturing technology for the generation of conformal assembly imbricated link data.

**Background**

**Body Armour**
- Used throughout history with the ultimate aim of reducing the likelihood of sustaining a life threatening injury, thus maximising survivability and mobility [1].
- Over 214,000 UK police officers wear body armour featuring a minimum level of protection to the UK Home Office Scientific Development Branch (HOSDB) Knife-Resistant level one (KR1) stab energy level [2,3].
- The KR1 stab impact energy of 24 joules (J) is the equivalent of dropping a blade with a mass of 1.9 kg, 1.3 meters at a velocity of 9.0 m/s. The maximum penetration at this level is 7.0 mm - with a 95.5% probability of protection [3].

**Armour in Nature**
- Natural armour has inspired body armour generation throughout history, with imbricated protective solutions such as Roman Lorica Squamata/Plumata, and more recently DragonSkin®.
- Scale armour has shown to efficiently manage impact energy by distributing energies over large areas. Such solutions have shown to reduce the likelihood of systematic armour failure as issues can be localised [4].

**Stab-Resistance in Additive Manufacturing**
- Existing research demonstrated that the following minimum material thicknesses were required to achieve penetration resistance to the HOSDB KR1 standard [5]:
  - 8.6 mm when manufacturing from virgin PA2200
  - 5.6 mm when using a 50:50 mix of recycled & virgin PA2200
- Previous research has also demonstrated the successful design, manufacture, and testing of Laser Sintered AM textile samples to the UK HOSDB knife resistant impact energy of 34J [5]. Samples,
  - were manufactured from a 50:50 mix of virgin & recycled PA2200
  - featured a scale thickness of 4.0 mm (5.6 mm min body thickness)
  - demonstrated a maximum 1.6 mm knife penetration

**Future Research**
- Areas identified to validate and further enhance the generation of AMBA:
  1. Realising and testing generatively modelled stab resistant AMBA using established stab resistant characteristics
  2. Increasing protection to UK HOSDB KR2 (33J) and KR3 (46J) stab resistant impact energies - including over test conditions
  3. Investigating the use of alternative materials to achieve suitable levels of protection
  4. To further investigate scale link design features to enhance protective and operational performance characteristics

**References**


**Generative Design**

Graphical generative algorithm use enables the real-time manipulation of the surface point data used to create AMBA links. Relationships can be established between primary link features, which can be modified through an array of input devices such as numerical sliders. The ability to simply modify characteristics can not only be used to generate an array of potential design solutions, but can also be used to input specific data appropriate for the development of AMBA assemblies prior to AM realisation.

The core generative process includes:

1. Establishing a series of primary modeling points
   - used to generate surface data
   - points can be manipulated within defined boundaries
   - modify the overall link design
2. Generating internal linking features
   - such as holes to link the body and leg between a series of scales
3. Creating the undersides linkage geometry
   - such as leg features
   - updates according to inputted scale material thickness
4. Orientating and assembling links
5. Generating conformal assembly data
   - currently performed via an external modelling process
   - uses the final generative modelled data

**Research Method**

To investigate the use of graphical generative algorithms for the generation of the link data used to create stab resistant Additive Manufactured Body Armour (AMBA) to UK HOSDB KR1 requirements.

Two primary objectives were developed:
- To identify key generative modelling activities for the development of imbricated link data
- Utilise the generative link data for the generation of a conformal assembly

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