Composite Protection: From Atoms to Application

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Aim of the Project

- Generate novel composite structures for high speed impact
  - Improved specific performance and reduction in back face deflection
- Inspiration from Nature
  - Horses hoof, teeth
  - Nacre
  - Exoskeleton helicoidal architecture
- Design driven by modelling
  - LS-DYNA impact modelling
- Requires materials testing for input
  - Focus lies in Ultra-High Molecular Weight Polyethylene (UHMWPE) fibre composites

Stomatopod Hierarchical Dactyl Club

Typical UHMWPE Impact Failure

Weaver et al [1]

Iremonger et al [2]
Ultra-High Molecular Weight PE

Why use UHMWPE fibre composites in impact scenarios?

- Dyneema® SK76 fibre has an extremely high specific strength
- Produces a high Cunniff c* parameter [3]

SEM of fibre over blade edge

Marissen [5]
Manufacturing

- Gel spun fibres are combined with polyurethane matrix
  - UD plies are cross-plied into a 0/90/0/90 configuration by DSM
  - Pre-cursor plies are stacked and hot-pressed at 120°C
  - Varied processing pressures, 10, 20, and 30 MPa
  - $V_f = 83\%$, ply thickness $\approx 70 \, \mu m$, fibre indentation between layers

**SEM of cross-plied pre-cursor**

**Hot-pressed fibre indentation**
Shear testing

- ±45 tensile shear specimen used to estimate properties
  - Highly non-linear result, initial $G_{12} \approx 86$ MPa
  - Dominated by fibre re-alignment toward the loading axis
  - Higher manufacturing pressures led to an increase in strength
  - Up to a 50% increase in initial stiffness at higher strain rate

Shear of the PU matrix

\[ \theta \approx 65^\circ \text{ after spring back} \]
Tensile Testing

- Low shear properties dictate the tensile response
  - Custom specimen required
  - Intra-laminar slip seen at the rear of the specimen
  - Large strain variation found in the gauge region
  - Unable to determine the effect from fibre indentation
Future Work

• Use test data to model impact scenarios
  – Homogenised 0/90 model to reduce the number of plies
  – Elastic-plastic material required with strain rate effects

• Use model to understand mechanisms of absorption
  – Parametric studies

• Use model to drive forward novel fibre architectures
  – Optimise design, likely through thickness property grading
Thanks to my supervisors and sponsors, and thank you for listening

Any Questions?