Advanced Technologies for the Bonding and De-bonding of Armour Structures (ArmourBond)

Konstantinos Chatzikypraios[1], Gary Critchlow[1], Simon Martin[1], Phillip Duke[2], Peter Webb[3]

[1]Loughborough University, Loughborough, LE11 3TU, UK
[2]Defence Science and Technology Laboratory, DSTL, Porton Down, SP4 0JQ, UK
[3]Permali Gloucester Ltd., Gloucester, GL1 5TT, UK

Loughborough University

Background

Multilayer vehicular armour systems (Figure 1) typically consist of a combination of:

- **Cover layer (strike plate)**
  - Provides environmental protection and constrains the ceramic layer
- **Ceramic layer**
  - Blunts, erodes and decelerates the impacting projectile
- **Metallic or Composite (backing) layer**
  - Absorbs the remaining kinetic energy of the projectile (plastic deformation)
- **Adhesive layer**
  - Joins the different layers/ materials of the structure
  - Controls the stress wave propagation, induced by the impacting projectile, via transmission and reflection phenomena, governed by the acoustic impedance mismatch between the functional layers
  - Acts as a mechanical insulator [1-4]

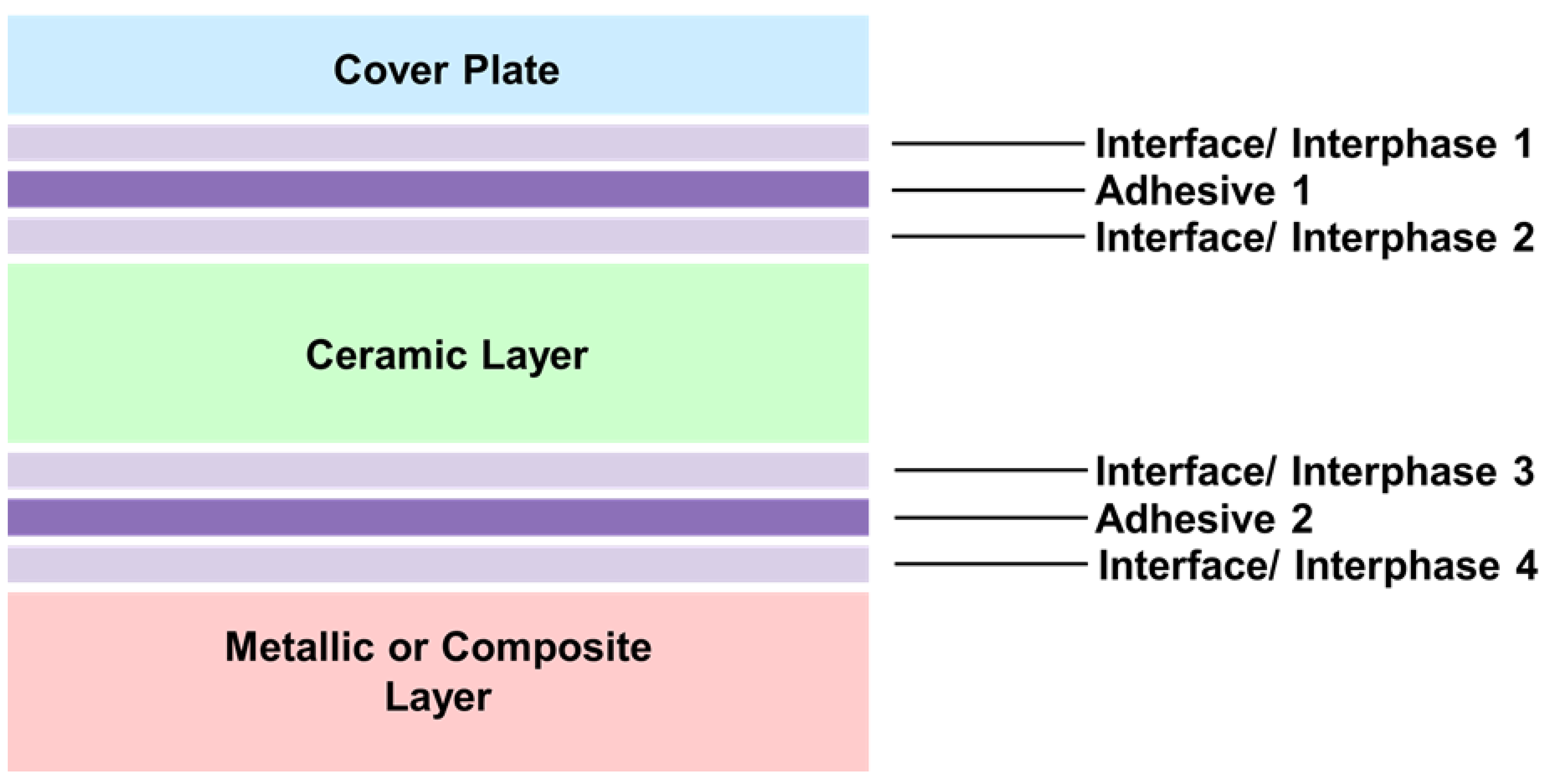

Figure 1. Example of a Multilayer Vehicular Armour System

Limitations of Current Multilayer Vehicular Armour Structures

- Existing bonding systems, which incorporate stiff and strong adhesives, such as epoxides, do not significantly attenuate the generated stress waves

  ➡ Transmitted stress waves (compressive stress) expose the occupants of the vehicle to damaging shock waves

- Internal shock waves reflection (tensile stress) causes the ceramic layer failure

  ➡ Reduced multi-hit capability

- The "fly light and fight heavy" requirement makes the debonding-on-demand concept attractive for the armour systems

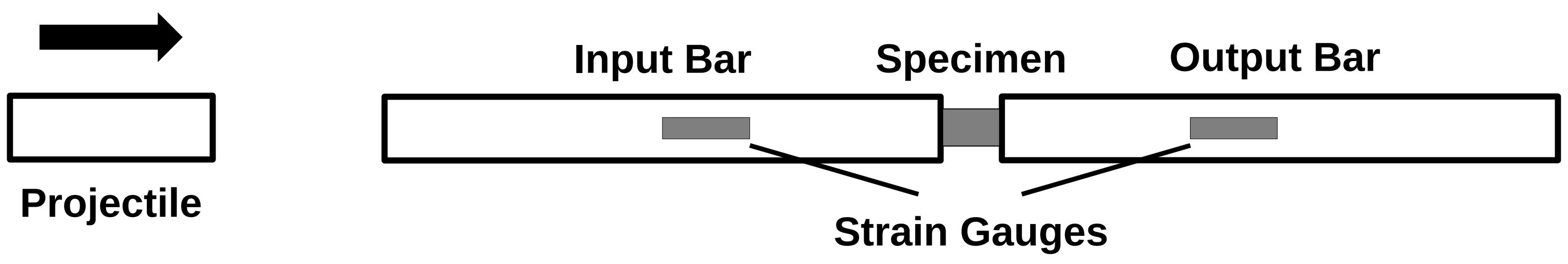

Figure 2. Example of an SHPB configuration [5]

Project Aims

- Study the effect of material selection, design and surface treatment on the adhesion, the mechanical and the ballistic performance of the armour systems
- Propose better energy absorbing armour systems with improved shock wave attenuation properties
- Develop debonding-on-demand systems based on semiconducting, reinforcing fillers in the adhesive phase, via an Ohmic heating effect
- Upscaling and testing, up to STANAG level 4, in real armour packs, in collaboration with Permali Gloucester Ltd.

High Strain Rate Adhesives Mechanical Response

- The mechanical response of materials couples tested at high strain rates (Split Hopkinson Pressure Bar, Figure 2), using a range of different adhesives and adhesive thicknesses, was determined
- Specimens were consisted of a front and a back, adhesively bonded, Aluminium cylinders (Figure 3)
  - Al cylinder length: 4 mm
  - Al cylinder radius: 8 mm
- Adhesive Types tested
  - Two-component epoxy (adhA)
  - Polyurethane (adhB)
  - Silicone (AdhC)
  - Toughened epoxy (AdhD)
- Adhesive thicknesses tested
  - 0.25, 0.5, 1.0 and 2.0 mm

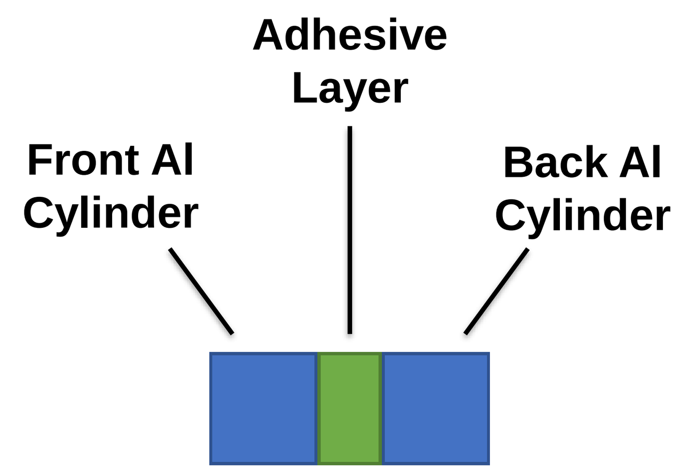

Figure 3. Al-adhesive-Al Specimen Configuration

SHPB Results & Conclusions

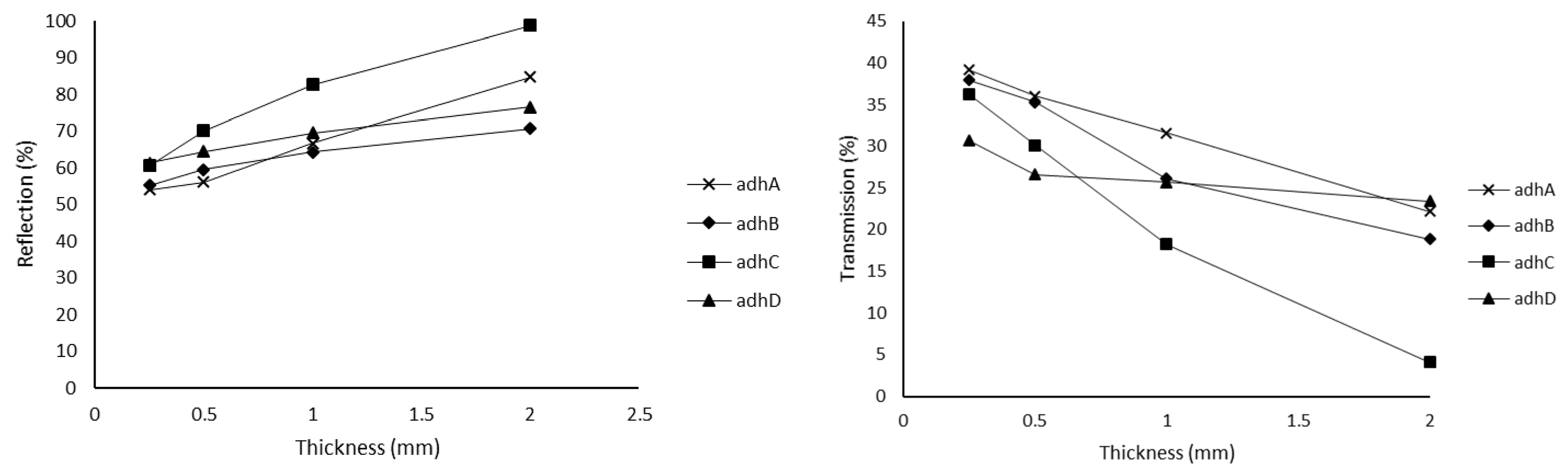

Figure 4. Promotion of input pulse: reflected (left) and transmitted (right) vs adhesive thickness

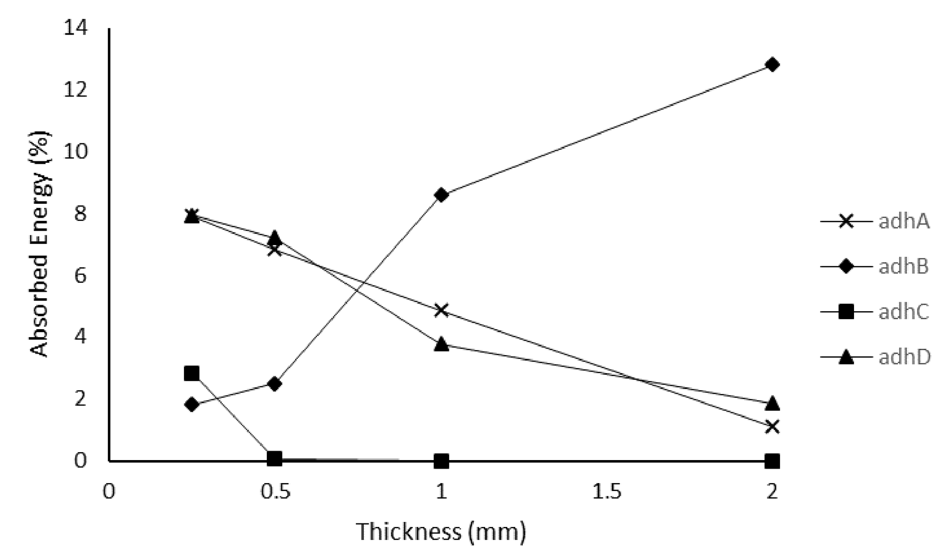

Figure 5. Absorbed energy (%) vs adhesive thickness

- Figures 4 and 5 show that the reflection and the transmission of the impacting energy is greatly dependent on the adhesive type and thickness and, therefore, they should be carefully considered during the materials couples design

dstl | Permali Gloucester

REFERENCES

[1] M. Grujicic, B. Pandurangan and B. d'Entremont, Mater. Des., vol. 41, pp. 380-393, 2012
[2] C.C. Holland, E.A. Gamble, F.W. Zok, V,S, Deshpande and R.M. McMeeking, Mech. Mater., vol. 91, no. P1, pp. 241-251. 2015
[3] M. Übeyli, R.O. Yildirim and B. Ögel, J. Mater. Process. Technol., vol. 196, no. 1-3, pp. 578-584, 2012
[4] C.Y Huang and Y.L. Chen, Mater. Des., vol. 91, pp. 294-305.2016
[5] M.A. Martínez, I.S. Chocron, J. Rodríguez, V. Sánchez Gálvez and L.A. Sastre, Int. J. Adhes., vol. 18, no. 6, pp. 375-383, 1998

CONTACT INFORMATION
Konstantinos Chatzikypraios
Department of Materials
Loughborough University
Leicestershire, LE11 3TU, UK
K.Chatzikypraios@lboro.ac.uk