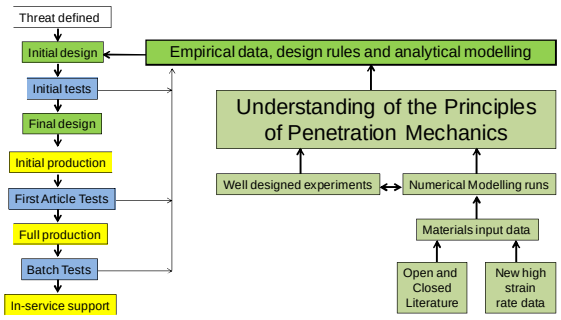
THE SCIENCE OF ARMOUR MATERIALS

By Ian Crouch

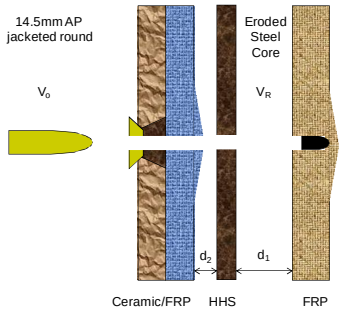
Part 1.1: Key message

"Understanding the possible failure mechanisms in an armour material is absolutely essential when designing improved armour materials and systems"

Part 1.2: An holistic approach to design



Part 1.2: Armour design – another upgrade – even more decisions!!



Design decisions

- Grade of steel [*]
- Thickness of steel [*]
- Air Gaps, d_1 [*] and d_2
- Grade of FRP [*]
- Thickness of FRP [*]
- Properties of FRP [*]
- Grade of ceramic
- Thickness of ceramic
- Grade of FRP support
- Thickness of FRP
- Obliquity of system
- Design velocity, V_D
- Armour engineering

Note: [*] FIXED

Part 1.2: Structural or appliqué?

Cast steel turrets, mantlets and hatch covers: H_V ~ 300

Appliqué armours: H_V ~ 500-700

Other disruptive armours: H_V ~ 350-450

Wear-resistant, high Mn, cast steel track pads: H_V ~ 220

Structural belly plates: H_V ~ 280

Weldable, structural, ballistic grades: H_V ~ 280-350

Part 1.2: Case Studies

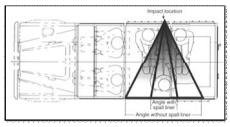
Selected examples where new armour materials have been used and/or developed.....and made a significant difference to the outcome!

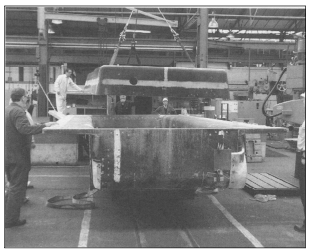
Part 1.2: Case Studies – Stillbrew up-armouring kit

Image of the Stillbrew Crew Protection Package as fitted to the UK Chieftain MBT in the 1980s. The kit first saw service as part of the Chieftain Mk 10 [Bovington Tank Museum, 2014]

- Original, highly-curved, turret castings in a WQ, Mn-steel
- Hv and through-hardening recognised (even against FSAPDS rounds!)
- New air-hardening grade of cast steel (now to UK DEF-STAN 95-26, 2011)

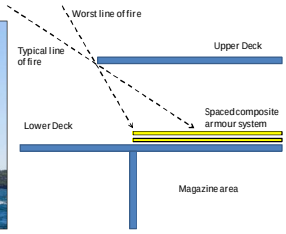
Part 1.2: Case Studies – UK ACAVP





- Converting spall liners into structural FRP armour materials
- RTM to Resin Infusion moulding
- E-glass NCF icw epoxy resin
- 10 year project!

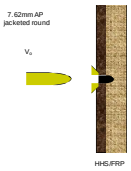
Part 1.2: Case Studies – RAN Huon Class Minehunter



- Solutions restricted to non-magnetic materials
- Locally-produced VBRI panels (E-glass NCF, VE resin)
- Spaced, composite armour solution

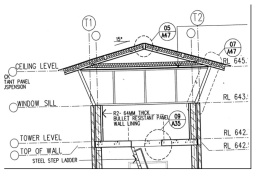
Part 1.2: Case Studies – Bushmaster up-armouring kit

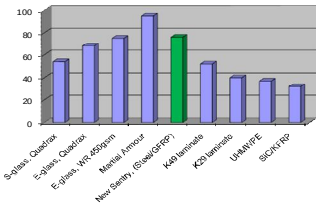
Up-armouring of early prototype destined for service in East Timor, circa 1997



- L1 to L2 through addition of FRP support panel
- FRP panels manufactured locally via PA-VBRI technique
- K900 aramid in VE resin matrix, with high Vf
- Bonded directly onto rear face of existing structural armour

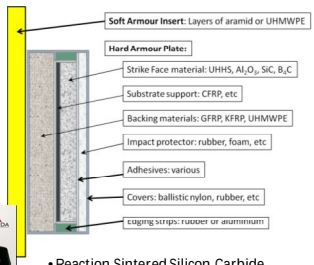
Part 1.2: Case Studies – Correctional Look-out Towers





- Incident in 1990s; escape by helicopter; guards fired upon from above
- Full protection from 7.62mm ball rounds
- Weight INSENSITIVE application
- Used steel/FRP hybrid principle, NewSentry armour, qualified to R2 AS2343
- Optimised steel properties to Hv ~450

Part 1.2: Case Studies – Hard Armour Plates



- Reaction Sintered Silicon Carbide
- VPP boron carbide
- ~20 designs; ~80,000 items
- ~$40m sales over seven years