Temasek Defence Systems Institute

Design of Multi-layered Protection against Guided Mortar Threat through Numerical Modeling

Lim Seng Kiat
Supervisor:
Dr. Rachael Hazael
Dr. Richard Critchley

Introduction

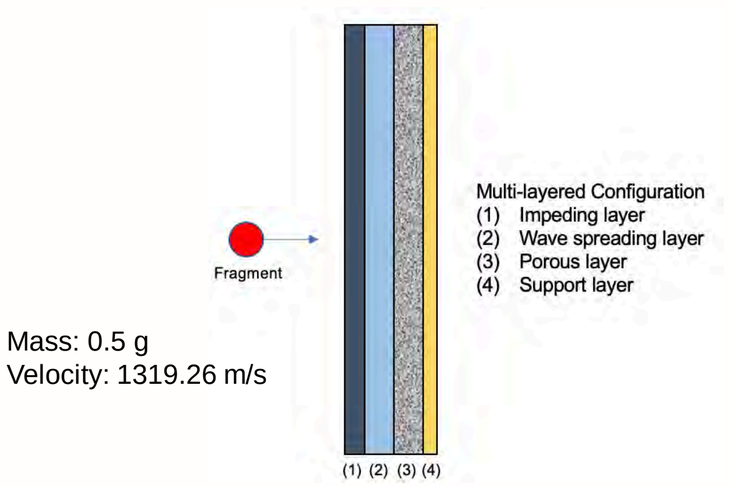
- Demand for light, simple to construct, low cost and effective fragmentation and ballistic protection
- Current protection methods are logistically demanding
- Precision mortar attack is the next major threat after IED
- Advanced lightweight material provides effective protection but are generally expensive

Aim

- Optimise a target configuration that consider the **performance, mass and cost**, based on high velocity mortar threat

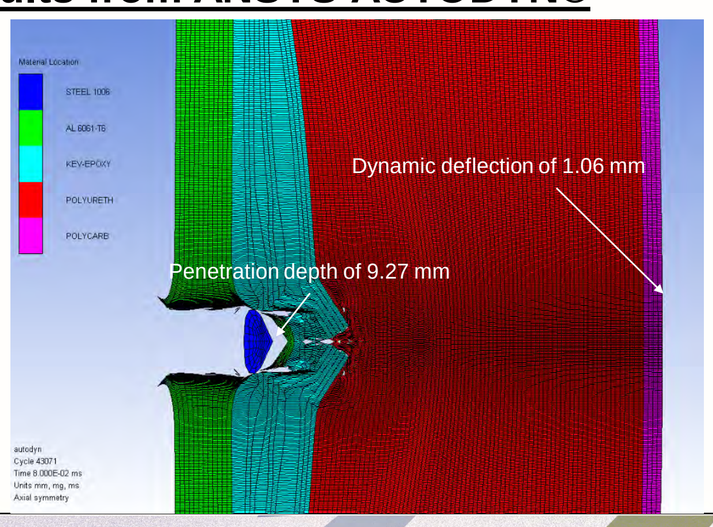
Approach

- Calculate velocity of fragment using Gurney equation
- Identify lightweight material based on desired properties
  - Aluminium (AL), Kevlar-epoxy (KE), Polyurethane (PU), Polycarbonate (PC)
- Perform simulation on monolithic layer
- Optimise using multi-layered configuration:
  - Impeding layer (AL) – impede the high velocity of fragment
  - Wave-spreading layer (KE) – anisotropic properties that spread the wave across the material instead of through it
  - Porous layer (PU) – filler material and act as shock absorber
  - Support layer (PC) – stop residual low velocity fragment



- Iterate AL and KE material thickness due to their mass and cost
- Total thickness assumed to be 50 mm
- 12 configurations were simulated

Sample Results from ANSYS AUTODYN®



Results – Observation 1

- Recommend combined thickness of AL and KE to be less than 12 mm
- Thickness at 13 mm lead to minimal increment in performance (-4%) but larger increase in mass (+15%) and cost (+31%)

Combined Thickness of AL and KE – first two layers (mm)	Average Mass (kg)	Average Cost (USD)	Average Penetration (%)
10	7.71	51.52	33.36
11	8.08 (+5%)	63.24 (+19%)	16.70 (-50%)
12	**8.44 (+8%)**	**74.96 (+31%)**	**10.79 (-68%)**
13	9.07 (+15%)	75.01 (+31%)	9.20 (-72%)
14	9.70 (+21%)	75.06 (+32%)	8.54 (-74%)

Results – Observation 2

- Ranked each configuration with equal weightage for each parameter
- 2C / 2G tied for best rank
  - Recommend to use 2G in view of better penetration performance and lower cost, with minimal increase in mass
  - Shows the importance of weightage criteria for each parameter, usually determined by the users

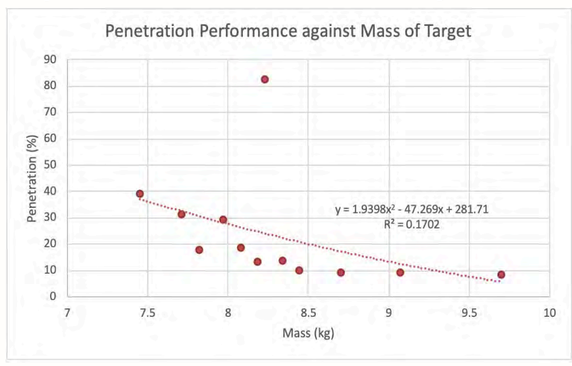
Config	Thickness	Mass (kg)	Cost (USD)	Penetration (%)	Mass Rank	Cost Rank	Penetration Rank	Total Point	Rank
2C	6,4,38,2	7.71	51.52	31.44	2	3	10	15	1
2G	7,3,38,2	7.97	39.86	29.34	4	2	9	15	1
2J	5,5,38,2	7.45	63.19	39.3	1	5	11	17	2
2F	7,4,37,2	8.34	51.57	13.8	8	4	6	18	3
2K	5,6,37,2	7.82	74.9	17.77	3	8	7	18	3
2B	6,5,37,2	8.08	63.24	18.54	5	6	8	19	4
2E	7,5,36,2	8.7	63.29	9.14	10	7	2	19	4
2I	8,2,38,2	8.23	21.89	82.64	7	1	12	20	5
2A	6,6,36,2	8.44	74.96	10.07	9	9	4	22	6
2L	5,7,36,2	8.18	86.62	13.17	6	12	5	23	7
2D	7,6,35,2	9.07	75.01	9.2	11	10	3	24	8
2H	8,6,34,2	9.7	75.06	8.54	12	11	1	24	8

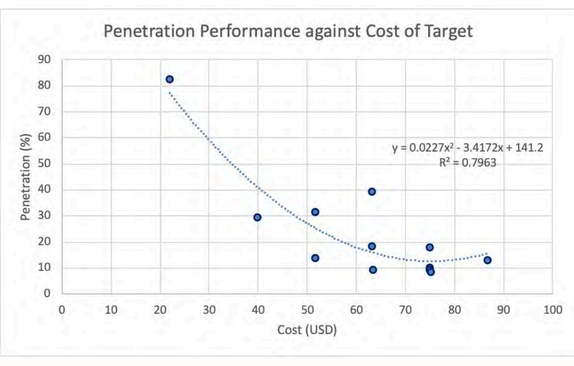
- Generate options for different requirements

Requirement	Configuration / Thickness (mm)	Mass (kg)	Cost (USD)	Penetration (%)	Rank
Lowest mass	2J (5,5,38,2)	7.45	63.19	39.30	2
Lowest cost	2I (8,2,38,2)	8.23	21.89	82.64	5
Best protection	2H (8,6,34,2)	9.70	75.06	8.54	8
Best ranked	2C / 2G (6,4,38,2) / (7,3,38,2)	7.71/7.97	51.52/39.86	31.44/29.34	1

Results – Observation 3

- Graph can be used as a reference to determine the penetration performance of the system based on mass and cost





Conclusion

- To consider over-engineering to keep pace with evolving threat scenario, while minimizing mass and cost of the system
- Study provides a simplified approach in balancing **penetration performance, mass and cost** of system

Cranfield University
NUS National University of Singapore