PENETRATION MECHANICS OF SOFT LAMINATES AND FABRICS

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ABSTRACT

♦The main objective of this research is to use QS-PST and Ballistic test methodology to understand the non-linear penetration damage mechanisms of soft laminates.
♦Penetration mechanics of thick-section composites have been recently developed following a Quasi-Static Punch Shear Test (QS-PST) experimental methodology.
♦Experiments are conducted at different support span to punch diameter ratios (SPR) under punch shear loading conditions to determine the penetration resistance force as a function of punch displacement.
♦Experiments are also conducted for different laminate thickness (0.50-mm ~ 9.00-mm) to identify the penetration damage mechanisms as a function of laminate thickness.
♦The Quasi-static penetration damage mechanisms are compared with ballistic penetration damage mechanisms, below and above the ballistic limit velocity of a 5.2-mm Ultra high molecular weight polyethylene (UHMWPE) laminate (20L = 464m/s for a 44 grain 30cal projectile).

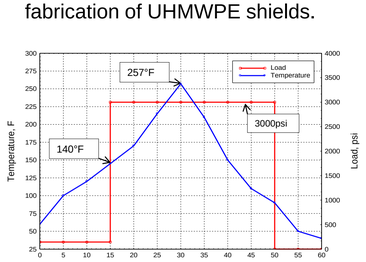
APPROACH

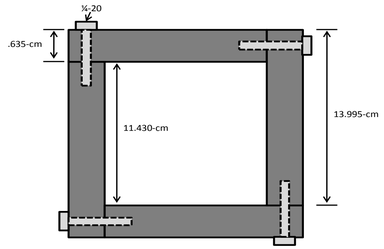
♦Processing of soft laminates
♦Quasi-static penetration testing
- Varying thickness
- Varying support spans

♦Ballistic penetration testing
♦Damage evaluation and comparison
♦Analysis of experimental data

MATERIALS AND PROCESSING

♦ Either UHMWPE shields are provided by the Army Research Laboratory with [0/90/0/90] sublaminate architecture or compression molding in a hot press is used to fabricate 114.3-mm x 114.3-mm soft laminates of varying thickness.
♦ARL laminates are received in 609.6-mm x 609.6-mm panels of 20 layers.
♦Compression molded soft laminates are fabricated from 304.8-mm x 304.8-mm soft laminate sheets, oriented in [0/90/0/90] direction.
♦Compression molding is done via hot press and following standards for fabrication of UHMWPE shields.

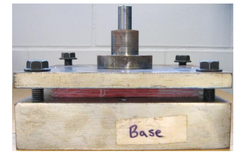


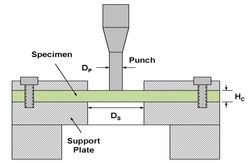


No. of S-L Layers	Stacking Sequence	Thickness, H_c, mm	Density, ρ, gm/cm^3	AD, kg/m^2
2L	$[(0/90/0/90)]_2$	0.518	1.001	0.519
4L	$[(0/90/0/90)]_4$	1.037	1.001	1.038
6L	$[(0/90/0/90)]_6$	1.555	1.001	1.557
8L	$[(0/90/0/90)]_8$	2.074	1.001	2.076
10L	$[(0/90/0/90)]_{10}$	2.592	1.001	2.595
12L	$[(0/90/0/90)]_{12}$	3.110	1.001	3.114
20L♦	$[(0/90/0/90)]_{20}$	5.184	1.001	5.191
30L	$[(0/90/0/90)]_{30}$	7.776	1.001	7.784

QS-PST METHODOLOGY

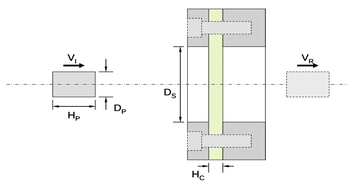
♦Proven capable of quantifying ballistic damage mechanisms and energy dissipation in thick-section composites.
♦Specimens are tested at different support span diameter (D_s) to a constant punch diameter (D_p) ratios [SPR = (D_s / D_p)].
♦The resulting load-displacement data for each test can be used to calculate the energy absorption by different energy absorbing damage mechanisms.





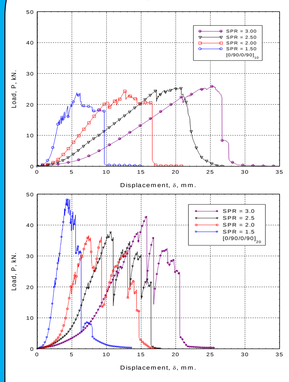
BALLISTIC TEST METHODOLOGY

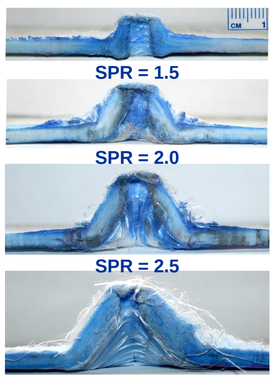
♦Ballistic experiments are conducted at Chesapeake Testing, MD, using a custom built ballistic test fixture.
♦Projectiles of diameter 7.62-mm and mass 2.85-g are used.
♦SPR for ballistic experiments is SPR = 13.33.



♦Impact velocity (V_I) and residual velocity (V_R) of the projectiles are measured using infrared velocity screens.

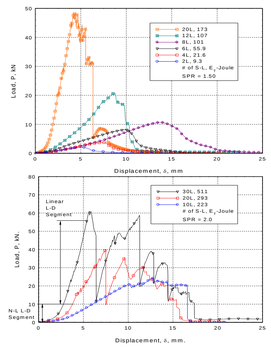
QUASI-STATIC PENETRATION RESISTANCE (QS-PR); FUNCTION OF SPR



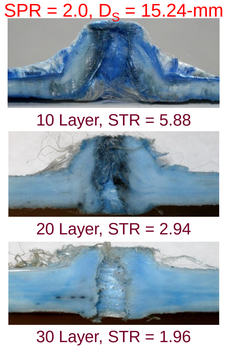


Stiffness of the linear load-displacement segment reduces with the increase in SPRs, however, the peak load obtained in different SPRs are comparable to each other

QS-PR; FUNCTION OF STR



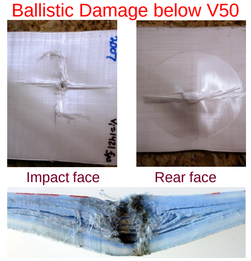
SPR = 2.0, D_S = 15.24-mm



♦As STR decreases with increasing thickness, pure shear deformation is observed Analysis of experimental data.
♦Combined tension-shear deformation and failure is observed in the rear side.
♦UHMWPE soft laminates can have both shear dominated and combined tension-shear dominated damage modes.

BALLISTIC DAMAGE

Ballistic Damage below V50

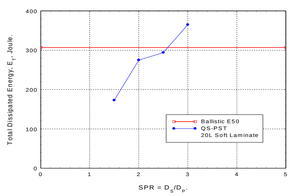


At impact velocity lower than V_{50} velocity, shear cutting of fibers, and physical delamination of the laminate is observed up to the back face. The last layer of fibers showed that The projectile completely stopped and rebounded back from the soft laminate.

Ballistic Damage above V50

At impact velocity above V50, the same damage mechanisms occurred as below V50 velocity with the only exception that all the sub-laminates showed shear cutting failure mode.

BALLISTIC LIMIT AND QS-PST ENERGY



♦The ballistic limit energy of the 20L soft laminate for a 0.30 caliber (44-grain) FSP can be calculated as E_{50} = 307 Joules
♦To the left is varying SPRs compared with the ballistic limit energy.
♦The ballistic limit energy is found to be close to the quasi-static energy dissipated at SPR = 2.00

CONCLUSIONS

♦There are 3 main damage modes for QS-PST: inter-laminar matrix damage, shear cutting of fibers, and combined tension-shear cutting/failure of fibers.
♦There are 4 main damage modes for Ballistic: sling shot failure, shear cutting of fibers, physical inter-laminar delamination, and wrinkles in the rear face of the soft laminate.

ACKNOWLEDGEMENTS

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