Emerging Nano and Advanced Materials

IIT DELHI INDUSTRY DAY 2019

Designing of hybrid soft body armour using unidirectional and high-performance woven fabrics impregnated with shear thickening fluid

Unsanhame Mawkhlieng, Abhijit Majumdar*

Department of Textile and Fibre Engineering

Abstract

This study aims to design soft body armour by evaluating the effect of ply configuration and hybridization. UHMWPE and PBO (Zylon®) yarns were used to make fabrics and along with commercially available Dyneema® UD SB51 sheet (250 g/m^2), 10 different soft armour panels (~4.9 kg/m^2) were prepared. The panels varied in the layering sequence of UD fabric, 2D neat and STF treated fabrics and were evaluated for ballistic performance in terms of back face signature (BFS).

The BFS was found to be below 44 mm in all cases. Placing UD fabrics in the strike face is more effective in reducing the BFS. Fabrics having higher modulus with low extension at the front and again at the back resulted in better performance. Finally, panels layer having STF treated fabrics showed lower BFS, particularly when placed as the backing.

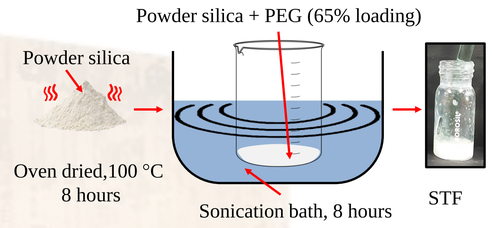
Introduction

- Approaches to reduce the weight of soft armour panels: STF impregnation and hybridization.
- STF treatment increases friction and energy absorption through the inherent STF phenomenon.
- Hybridization works by synergistically combining the complementary properties of different materials to improve performance and to reduce weight.
- Fabric structure also plays an important role: UD, 2D, etc.
- UD is monolithic in structure; able to deform and blunt the bullet's sharp tip.

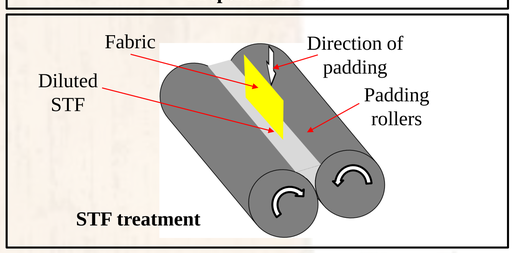
Materials and Methods

Fabric code	Yarn type	Linear density (denier)	Fabric sett (inch^{-1})	Areal density (g/m^2)
Z	Zylon®	1000	30×30	282
PE	UHMWPE	1300	23×23	307

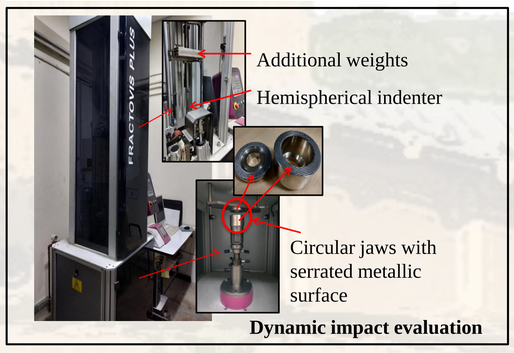
Panel code	Alternative code	No. of layers	Areal density of armour panel (kg/m^2)
U/Z	A	10L/8L	4.84
U/PE	B	10L/8L	4.82
U/Z/PE	C	10L/4L/4L	4.85
U/PE/Z	D	10L/4L/4L	4.85
U/Z/Z*	E	10L/4L/4L	4.97
U/PE/PE*	F	10L/4L/3L	4.75
U/Z/PE*	G	10L/5L/3L	5.0
U/PE/Z*	H	10L/4L/4L	4.92
PE/Z*/U	I	4L/4L/10L	4.97
Z/PE*/U	J	5L/3L/10L	4.97



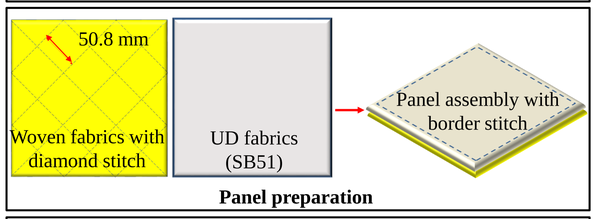
Preparation of STF



STF treatment



Dynamic impact evaluation



Panel preparation

BFS measurement

Conclusions

- Soft armour panel with 4.9 kg/m^2 areal density was designed.
- Achievable BFS= 30-32 mm.
- STF treatment reduces the BFS.
- Design strategy: UD sheet in the front layer/woven fabric in the middle layer/woven fabric at the back, preferably STF treated.

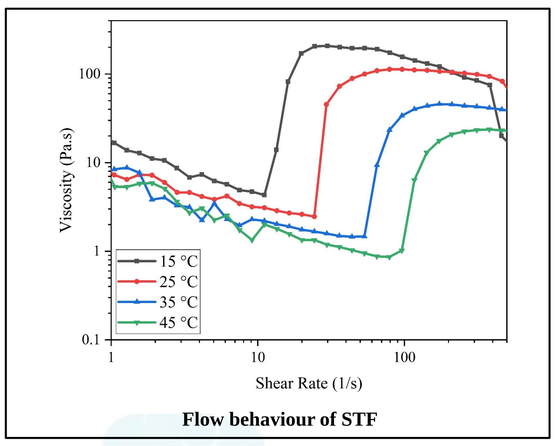
Industrial Significance

Soft armour panels with areal density 4.9 kg/m^2 giving BFS less than 44 mm are achievable with hybridization and STF treatment.

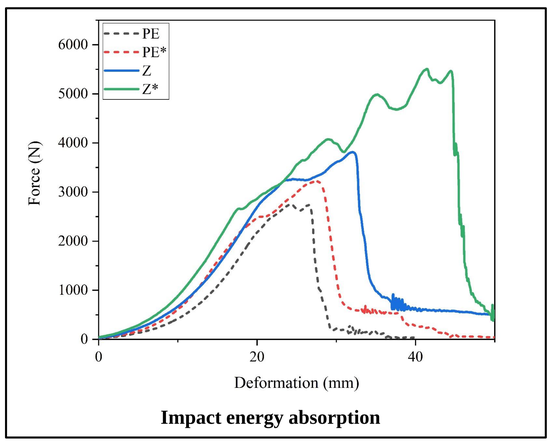
Technology Readiness Level

TRL 3

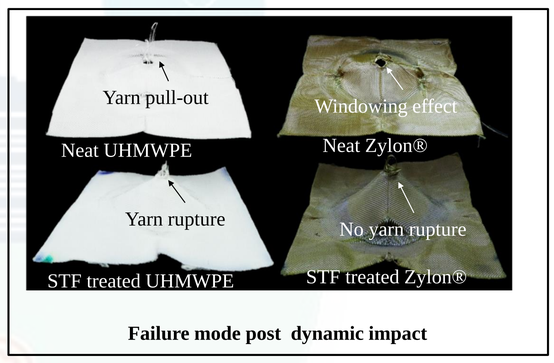
Results



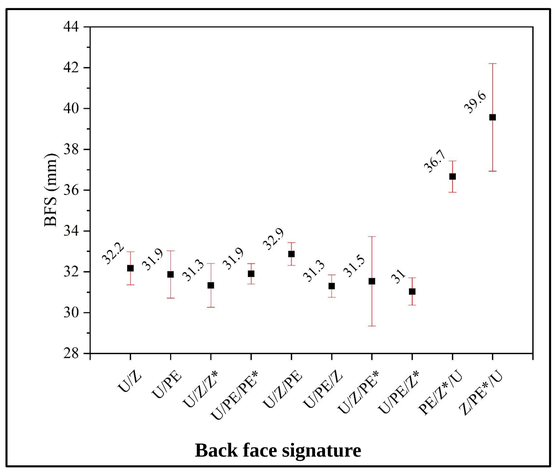
Flow behaviour of STF



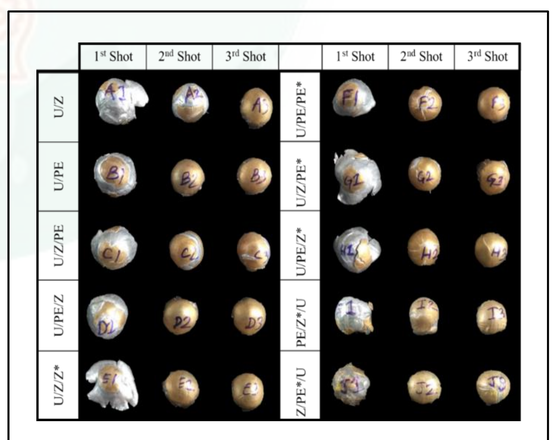
Impact energy absorption



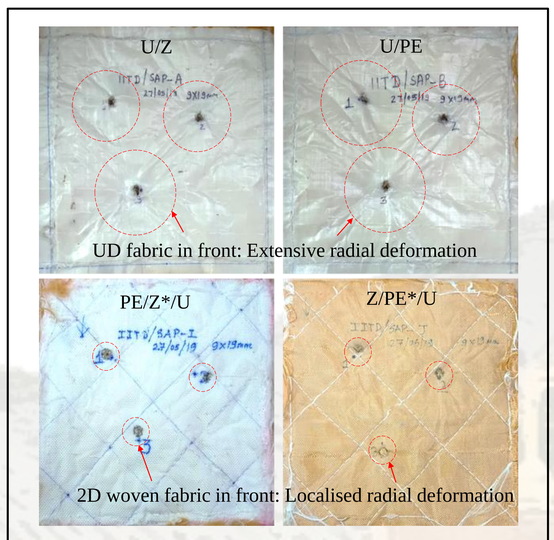
Failure mode post dynamic impact



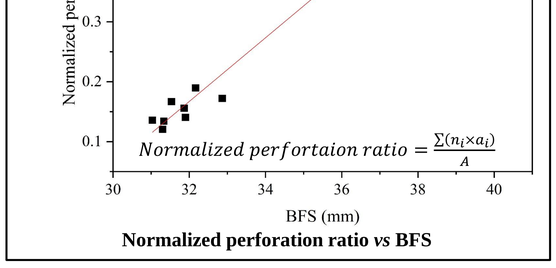
Back face signature



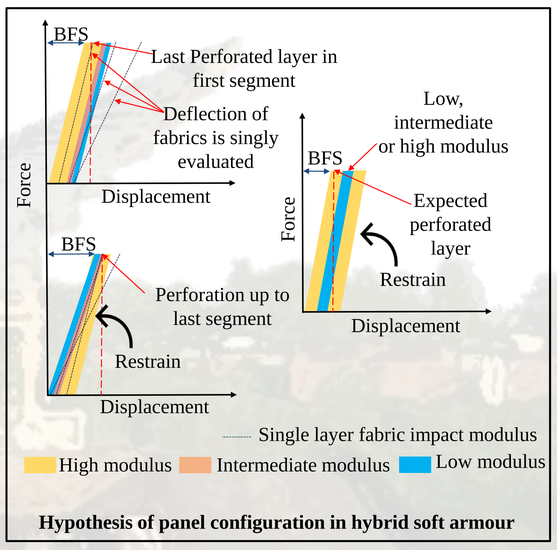
Bullet deformation post ballistic impact



Radial deformation at the strike face



Normalized perforation ratio *vs* BFS



Hypothesis of panel configuration in hybrid soft armour

References

- Lee YS, Wetzel ED, Wagner NJ. The ballistic impact characteristics of Kevlar woven fabrics impregnated with a colloidal shear thickening fluid. J Mater Sci 2003;38:2825–33.
- Park JL, Chi YS, Kang TJ. Ballistic performance of hybrid panels composed of unidirectional/woven fabrics. Text Res J 2013;83:471–86.
- Chen X, Zhou Y, Wells G. Numerical and experimental investigations into ballistic performance of hybrid fabric panels. Compos Part B 2014;58:35–42.
- Provost B, Boussu F, Coutellier D, Vallee D, Rondot F, Nussbaum J. Armouring solutions against high-velocity impact using 2D laminates and 3D warp interlock composites. J Ind Text 2014;43:606–26.
- Park JL, Yoon BI, Paik JG, Kang TJ. Ballistic performance of p-aramid fabrics impregnated with shear thickening fluid; Part I - Effect of laminating sequence. Text Res J 2012;82:527–41.

Acknowledgement

The authors are thankful to Defence Research and Development Organization (DRDO), India for providing financial assistance for this research work through Grant No. DFTM/03/3203/M/01/JATC.