DEVELOPMENT OF AN ADVANCED COMPOSITE MATERIAL MODEL SUITABLE FOR BLAST AND BALLISTIC IMPACT SIMULATIONS

C. F. Yen, and B.A. Cheeseman
Army Research Laboratory
AMSRL-WM-MD
Aberdeen Proving Ground, MD 21005-5069

ABSTRACT

A robust composite progressive failure model has been successfully developed to account for the strain-rate and pressure dependent behavior of composite materials subjected to high velocity ballistic impact. This composite failure model has been used to quantify the ballistic impact behavior of various composite panels with reasonable accuracy. Application of the current composite model for designing lightweight composite armor with various three dimensional fiber architectures is under progress.

1. INTRODUCTION

The U.S. Army's proposed FCS requires significant advances in survivability technology to achieve system-level performance that exceeds that of current combat vehicles in platforms which weigh less than 15 tons. Composite materials are well suited to this role as they possess superior stiffness and strength-to-weight properties over many other classes of materials, and their incorporation into armor and blast resistant structures will provide mass efficient integral survivability for the warfighter in the FCS. To develop the novel passive armor systems required for the FCS, the U.S. Army Research Laboratory is employing advanced numerical simulations and experimental techniques to evaluate a range of armor solutions; however, in order to accurately capture the armor performance using numerical simulations, the composite material behavior must be modeled correctly. Towards these ends, a robust material model for composites subjected to blast and ballistic impact has been developed.

2. APPROACH AND RESULTS

Previous studies have shown that certain composite materials subjected to high rate loadings, such as blast and ballistic impact, exhibit significant strain rate sensitivity of both their stiffness and strength. Furthermore, high velocity ballistic impact as well as blast shock loading introduces large pressure in the contact regions, which has significant effect on the target material failure behavior. A robust composite progressive failure model has been successfully developed and integrated into LS-DYNA for accurate quantification of strain-rate and pressure dependent ballistic impact behavior of unidirectional and plain weave composite laminates [1,2]. This failure model has been used to quantify the ballistic performance of composites with various fiber architectures [3,4]. Typical results for an E-glass/Epoxy woven composite laminate subjected to FSP impact are shown in Figure 1. It shows the deformation, penetration and erosion of the system for a ballistic impact of FSP with a 30^0 oblique incident angle. The results clearly demonstrate that the composite eroding failure due to fiber failure modes of punch shear, crush, and tension were introduced by the plastically deformed projectile under combined linear and rotational impact velocities. The predicted residual velocity of the projectile is within 4% accuracy of the measured value.

3. CONCLUSIONS

The present composite material model can provide insight into the damage development and progression that occurs during the ballistic impact or blast loading of lightweight composite armor. By identifying specific damage mechanisms that occur, reinforcement schemes can be determined to suppress them, which may ultimately enhance the survivability of the FCS. Recent experiments have shown interlaminar damage suppression is critical to multi-hit performance. Minimizing this interlaminar damage is typically done by introducing reinforcements in the thickness direction. An extension of the current composite material model to include three dimensional fiber architectures such as triaxial weave and 3D woven fabrics has been under progress.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **00 DEC 2004**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Development Of An Advanced Composite Material Model Suitable For Blast And Ballistic Impact Simulations**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Army Research Laboratory AMSRL-WM-MD Aberdeen Proving Ground, MD 21005-5069**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001736, Proceedings for the Army Science Conference (24th) Held on 29 November - 2 December 2005 in Orlando, Florida. , The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**2**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

REFERENCES

1. Yen, C.F., "Ballistic Impact Modeling of Composite Materials," Proceedings of the 7th International LS-DYNA Users Conference, Dearborn, MI, May 19-21, 2002.
2. Yen, C.F., "Modeling of Composite Materials under Strain-Rate Loading Conditions," Proceedings of the 18th Annual Technique Conference American Society of Composites, MB5-224, Gainesville, FL, October 19-22, 2003.
3. Yen, C.F., and Caiazzo, A.A., "Design Methodology and Validation for Multifunctional Composite Armor," MSC Technical Progress Report, U.S. Army Research Laboratory, Contract No. DAAD17-01-C-0111, July 2002.
4. Yen, C.F., and Morris, A., "Blast/Ballistic Impact Damage Evaluation of Marine Composite Structures," MSC TFR IH19, NSWCCD, Contract No. 5007-203-45/02, January 2003.

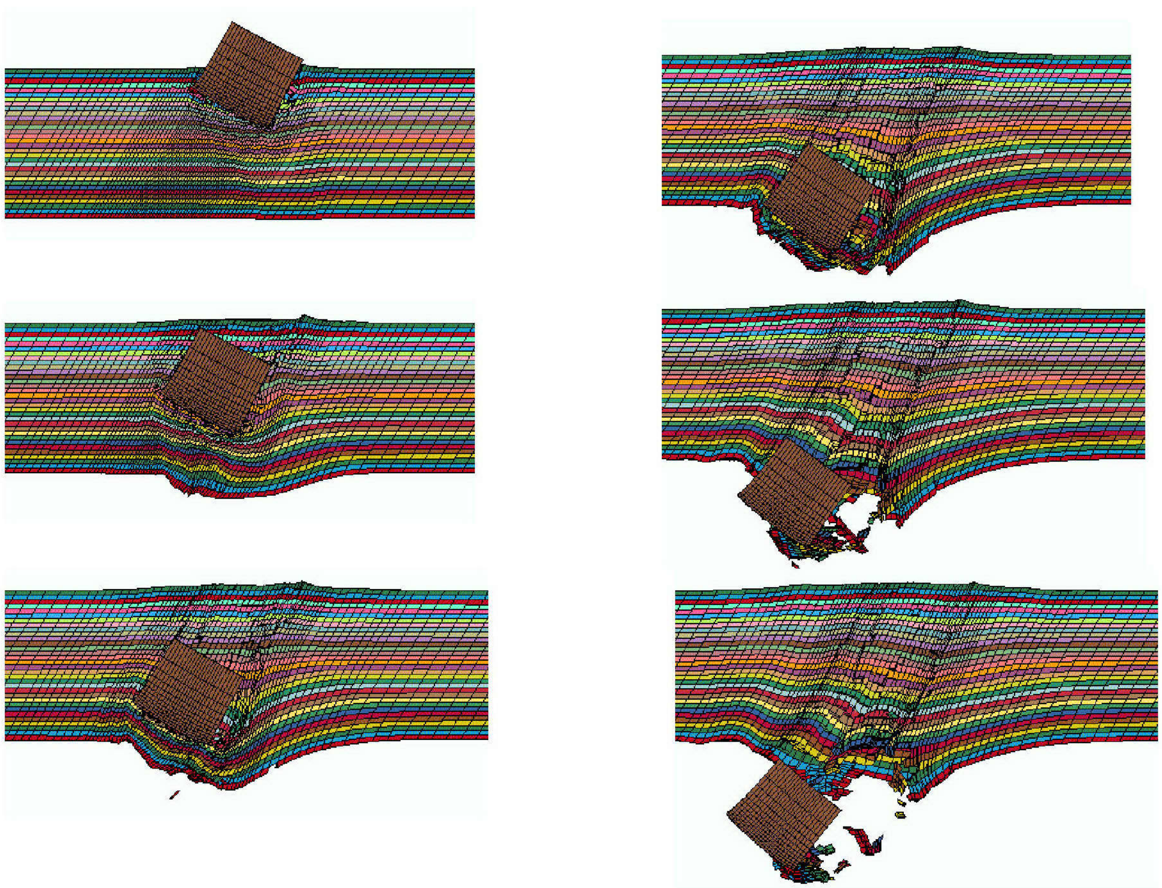

Figure 1: Deformed Mesh Plots of a Composite Panel Subjected to FSP2 Impact at 0.01 msec, 0.02 msec, 0.03 msec, 0.04 msec, 0.5 msec, and 0.6 msec.