A STUDY ON COMPUTATIONAL ANALYSIS OF IMPACT RESISTANCE PROPERTIES OF T300/EPOXY COMPOSITE

S. Lee[1], G. Zhao[2], S. B. Lee[3], C. Y. Han[4] and C. Cho[†1]

[1] Department of Mechanical Engineering, Inha University, 253 Yonghyundong, Namgu, Incheon, Korea
[2] Department of Aerospace Engineering, Xi'an Jiaotong University, Xi'an 710049, China
[3] High Safety Vehicle Core Technology Research Center, Inje University, 607 Obangdong, Gimhae, Korea
[4] Department of Mechanical Engineering, Inje University, 607 Obangdong, Gimhae, Korea
[†] Corresponding author

Introduction

The ballistic impact properties of carbon fiber reinforced (CFR) composites have attracted much attention since the CFR are mainly used to provide protection against impact [1-5]. Although numerous models have been proposed to predict the impact resistance of these materials [1],[6], the structural impact response characteristics of CFR composite materials have not been extensively investigated especially the impact energy absorption and penetration phenomena during high velocity impacts.

In this study we investigated the experimental and numerical results of impact velocity and energy absorption of T300/epoxy composite laminates. The results can improve the relation between impact velocity and energy absorption, and hence increase the accuracy of numerical analysis of composites under impact such as in fracture mechanics field

Materials and Methods

The specimens were prepared from laminated unidirectional carbon fiber epoxy resin prepregs containing 40±2.5% resin. The densities of the resin and fiber are respectively 1.27±0.07 and 1.76±0.04 g/cm^3. The composites were cured at 125℃ and stored at about 23℃ and 50% relative humidity. The specimen properties are listed in Table 1. The specimens' size was 90 × 90× 2.4 mm. The stacking sequence of the laminates were [(45/-45)4]s and [(0/45/90/-45)2]s. All the specimens were subjected to high velocity impact testing conducted by using a high speed gas gun. A hemispherical cupped steel bullet of mass 19.99g was used as the projectile. The bullet is a solid cylinder of size 12.7mm in diameter and 22.35mm in length (Fig. 1).

Fig. 1 high speed gas gun(Left) and impacting bullet(Right)

Table 1. The properties of T300/epoxy specimen

Load Type	Property	0°	90°
Tension	Stiffness (GPa)	125±15	9.5±1.5
	Strength (GPa)	1.3	0.035
Compression	Stiffness (GPa)	120±20	8.25±2.25
	Strength (GPa)	1.15	0.017
Shear in plane Modulus(GPa)		5.5±1	
Poisson ratio		$\nu_{12}=\nu_{13}=0.3$	$\nu_{23}=0.49$

Computational Analysis

For the finite element analysis, ABAQUS/Explicit is used. The 3-dimensional geometry of specimen and bullet are modeled as same with the experiments. In general, composite laminates are modeled as 2D element like continuum shell, however due to the penetration phenomena, differently oriented 3D elements are used like Fig 2.

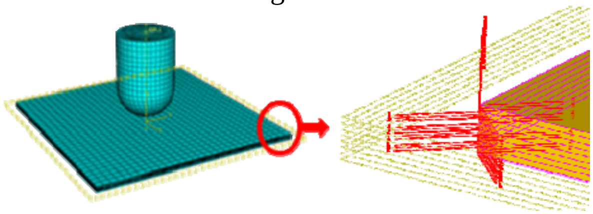

Fig. 2 Finite element model (Left) and material orientation (Right) of [(45/-45)$_4$]s laminates

The number of elements and nodes are 24,845 and 27,818 respectively. Since anisotropic model is assumed, Hill's plasticity is used as failure model. The bullet is regard as a rigid body controlled by a reference point. The stiffness degradation and element deletion techniques are applied to replicate the penetration phenomena. All figures of simulation result in the result and discussion section are actually continuous.

Result and Discussion

a. Failure modes of target plate

At the impacting velocity less than the ballistic limit velocity, simulation results show the bullet did not penetrate the composite plate. This limit velocity is important for the criterion of energy absorption as well as rate-dependent behavior, i.e. viscoelasticity.

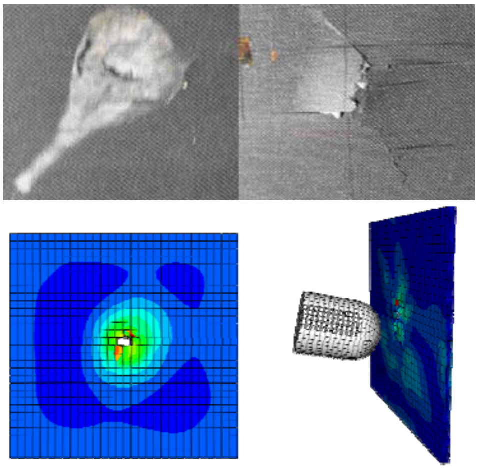

Fig. 3 Failure modes of targets at impacting velocity less than ballistic limit velocity (45 m/s); deformation result along impacting-axis (lower left) and von-Mises stress result (lower right)

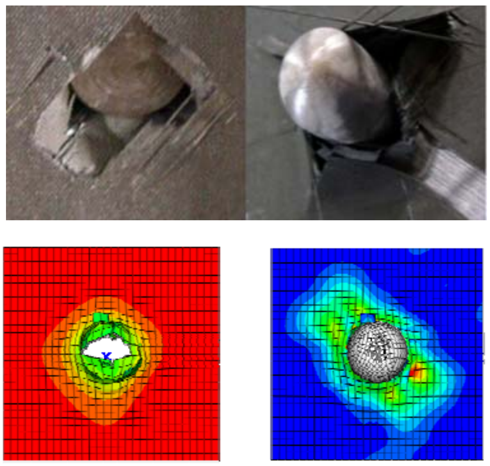

Fig. 4 Failure modes of targets at ballistic limit velocity (50 m/s); Deformation result along impacting-axis (lower left) and von-Mises stress result (lower right)

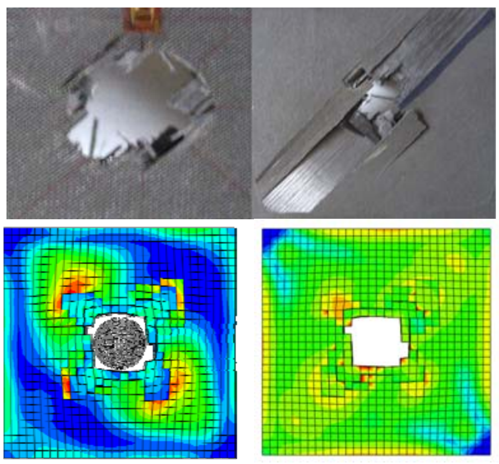

Fig. 5 Failure modes of targets at impacting velocity more than ballistic limit velocity (260 m/s); von-Mises stress result (lower right) and scalar stiffness degradation result (lower left)

b. Comparison Energy absorption

Fig. 6 shows kinetic energy loss increases in accordance with increasing impact velocity at the velocity more than ballistic limit velocity, around 55 m/s.

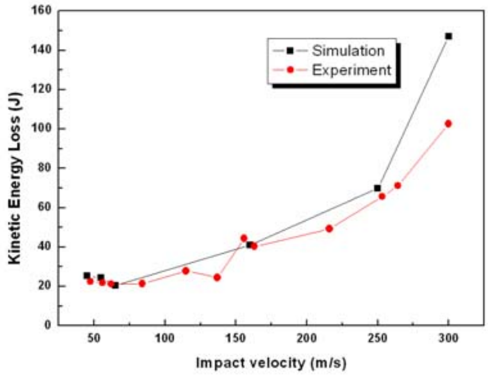

Fig. 6 Comparison between energy loss results of simulation and experiment

Conclusion

The accuracy of material characterization and impact analysis are improved for laminate composite of 3-dimensional model subjected to impact loading. In finite element analysis, the impact failure of anisotropic material, especially laminate composite, is highly dependent on definition of the damage criterion and stiffness degradation.

References

1. Lee, S-WR. and Sun, CT. (1993). Dynamic penetration of graphite/epoxy laminates impacted by a blunt-ended projectile, Composites Science and Technology, 49(4):369-380.
2. Fujii, K., Aoki, M., Kiuchi, N., Yasuda, E., and Tanabe, Y. (2002). Impact perforation behavior of CFRPs using high-velocity steel sphere, International Journal of Impact Engineering, 27(5):497-508.
3. Ulven, C., Vaidya, UK. and Hosur, MV. (2003). Effect of projectile shape during ballistic perforation of VARTM carbon/epoxy composite panels, Composite Structures, 61(1-2):143-150.
4. Zhu, G., Goldsmith, W. and Dharan, CKH. (1992). Penetration of laminated Kevlar by projectiles — I. Experimental investigation, International Journal of Solids and Structures, 29(4): 399-420.
5. Naik, NK. and Shrirao, P. (2004). Composite structures under ballistic impact, Composite Structures, 66(1-4):579-590.
6. Taylor, JW. and Vinson, JR. (1990). Modeling ballistic impact into flexible materials, AIAA Journal, 28(12): 2098-2103.
7. Morye, SS., Hine, PJ., Duckett, RA., Carr, DJ. and Ward, IM. (2000). Modelling of the energy absorption by polymer composites upon ballistic impact, Composites Science and Technology, 60(14):2631-2642.