INVESTIGATION OF EXPERIMENTAL RESEARCH ON THE LOW VELOCITY IMPACT DAMAGE BEHAVIOR OF NCF COMPOSITE PLATES – COMPLAS XII

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Abstract. In this study an experimental investigation is performed on the impact response of non-crimp fabric composite plates at room temperature. Chopped strand mat combi is used as reinforcing material and two kinds of matrix; epoxy and polyester, are also used as resin material in the composite plates. All specimens used in experiments are manufactured by vacuum assisted resin infusion method at Atard Defence and Aerospace Advanced Technology Application Research and Development Inc. An instrumented drop weight impact testing machine Instron-Dynatup 9250 HV is used for impact testing. Impact tests are performed under various impact energies ranging from initiation of damage to final perforation. Damage processes of the samples are analyzed from cross-examining load–deflection curves, energy profiling method and damaged specimens.

1 INTRODUCTION

The multiaxial reinforcements, Figure 1, (non-crimp or stitch-bonding fabrics) has allowed for faster fabrication of parts with better physical and mechanical properties. Parts made from these reinforcements have led to cost effective solutions for a variety of applications including marine, transportation, infrastructure, sports and recreation and aerospace. The cost effective solution begins with engineering the laminate requirements at the point of fabric manufacture. The strength demands can be engineered right into the reinforcement by considering fiber weight and fiber angle of any given ply. Multiaxial reinforcements can be engineered to meet specific requirements and perform multiple tasks such as providing good surface finish, impact and abrasion resistance, and structural integrity, all in one fabric. [1]

Low velocity impact tests of non-crimp fabric composite are limited. The some of them are as follows: Atas et al. [2] studied an experimental investigation on the impact response of repaired and unrepaired glass/epoxy composite plates. They reported that the fiber fractures through repair line as well as the delaminations became dominant modes for repaired samples.

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Shyr et al. [3] worked an investigation into the damage characteristics and failure strengths of composite laminates at low velocity impact tests. They found that major damages were matrix cracking, delamination and fiber breakage at the back surface. Shyr et al. [4] carried out low velocity impact responses of hollow core sandwich laminate and interply hybrid laminate. The results of their study showed that the inlaid materials played a very important role in the impact behavior and damage characteristics of the laminates. Saito et al. [5] determined the impact damage and growth behavior of T700 multi-axial stitched CFRP. Sugie et al. [6] carried out effect of CF/GF fibre hybrid on impact properties of multi-axial warp knitted fabric composite materials. They have developed the design manual for the fibre hybrid to improve the energy absorption. Vallons et al. [7] determined the impact and post-impact static and fatigue tensile properties of a carbon fiber/epoxy NCF composite and compared their properties to those of a carbon fiber/epoxy woven fabric composite, for two impact energies (3.5 and 7 J). They found that the projected damage area after impact was larger for the NCF composite than that for the woven fabric composite for both impact energies. Ağır [8] studied investigation of impact responds of composite plates manufactured with stitch-bonded non-crimp glass fiber fabrics. Polyester resin composites (biaxial, triaxial, quadraxial), up to 50 J impact energy, absorbed energies are nearly same. It is found that the perforation threshold of triaxial/polyester composite is approximately 27% and 22% higher than that of the quadraxial/polyester and biaxial/polyester composites, respectively. In addition, the epoxy resin composite, quadraxial composite transfer energy 74% higher than biaxial composite to the impactor.

2 EXPERIMENTAL

The composite plates were manufactured with stitch-bonded non-crimp glass fiber fabrics supplied from Metyx (Telatex) and produced by vacuum infusion method at Atard firm in Turkey. The stitched biaxial glass fibers with chopped strand mat were used as reinforcing material and two kinds of resine; epoxy and polyester, were used as matrix materials in the composite plates. The mixing ratios of the resins are listed in Table 1a.

Table 1a: The mixing ratios of the resins

Resin		Hardener	Accelerator
Epoxy	PGKEH 1200	10:0.34	-
Polyester	Dewilux Dewester 196	10:0.15	10:0.4

The stacking sequence and properties of non-crimp fabrics are given in Table 1b.

Table 1b: The stacking sequence and properties of non-crimp fabrics

Specimen ID	The stacking sequence	Specimen thickness (mm)	Fabric	Areal Density (g/m^2)
ME	[(0,90,CSM)/(±45,CSM)/(CSM/±45)/	5	(0,90,CSM)	675
MP	(CSM,90,0)]$_s$		(±45,CSM)	693

*M: Stitch-bonded biaxial with chopped strand mat (CSM), E: Epoxy, P: Polyester

As seen in the figure 1 that composite plates were manufactured by vacuum infusion process which is a technique that uses vacuum pressure to drive resin into a laminate. After manufacturing process, the composite specimens with dimensions of 100mm x 100mm were trimmed from the laminated plates. Instron-Dynatup 9250 HV are used for impact testing. The impactor has a hemispherical nose (12.5 mm diameter). The mass of the impactor is 6.32 kg. Impact tests are accomplished from 10J impact energy to perforation.
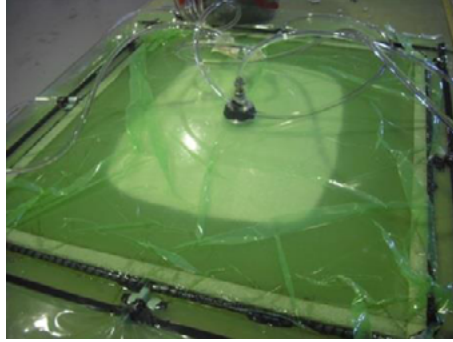

Figure 1: Manufacturing of composite plates.

3 RESULTS AND DISCUSSION

Figure 2 shows the energy profile diagram, the relationship between impact and absorbed energy, of MP and ME composites. As seen, the penetration thresholds of MP and ME composites are obtained for 87.94J and 85.54J, respectively. The perforation thresholds are also obtained for 92.49J and 90.17J, respectively. The absorbed energies are almost the same up to 30J impact energy. For the next impact energies, the absorbed energies of ME composites are higher than MP composites.
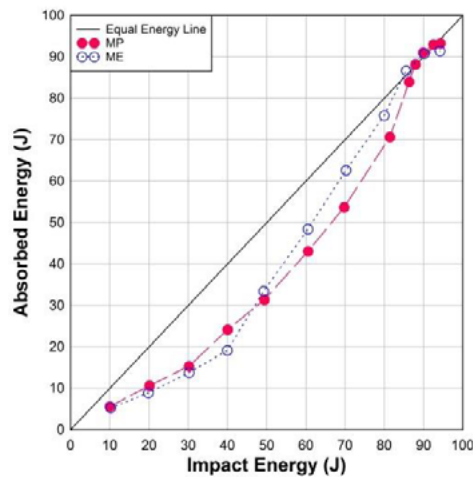

Figure 2: The energy profile diagram of MP and ME composites

Figure 3 shows load-deflection curves for ME and MP composites at increasing impact energy. As seen in Figure 3a, Hertzian failure occurred in MP composite at about 3 kN. However, It was not observed for ME composite until perforation threshold.
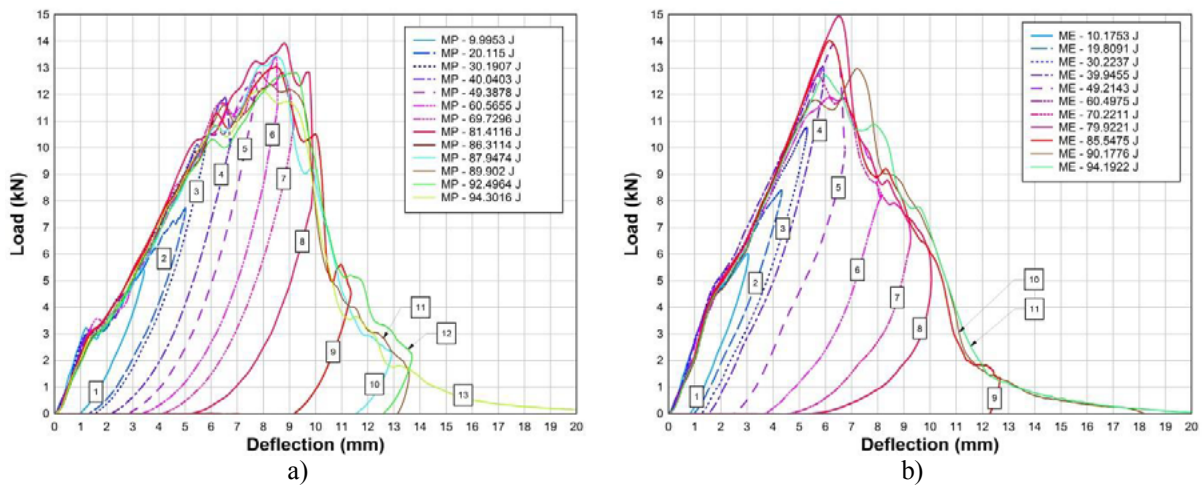
Figure 3: Load-deflection curves for the a) MP and b) ME composites

The bending stiffness of ME composite is higher than MP composite. Therefore, 60J impact energy, the penetration and perforation thresholds are chosen for understanding of damage modes.
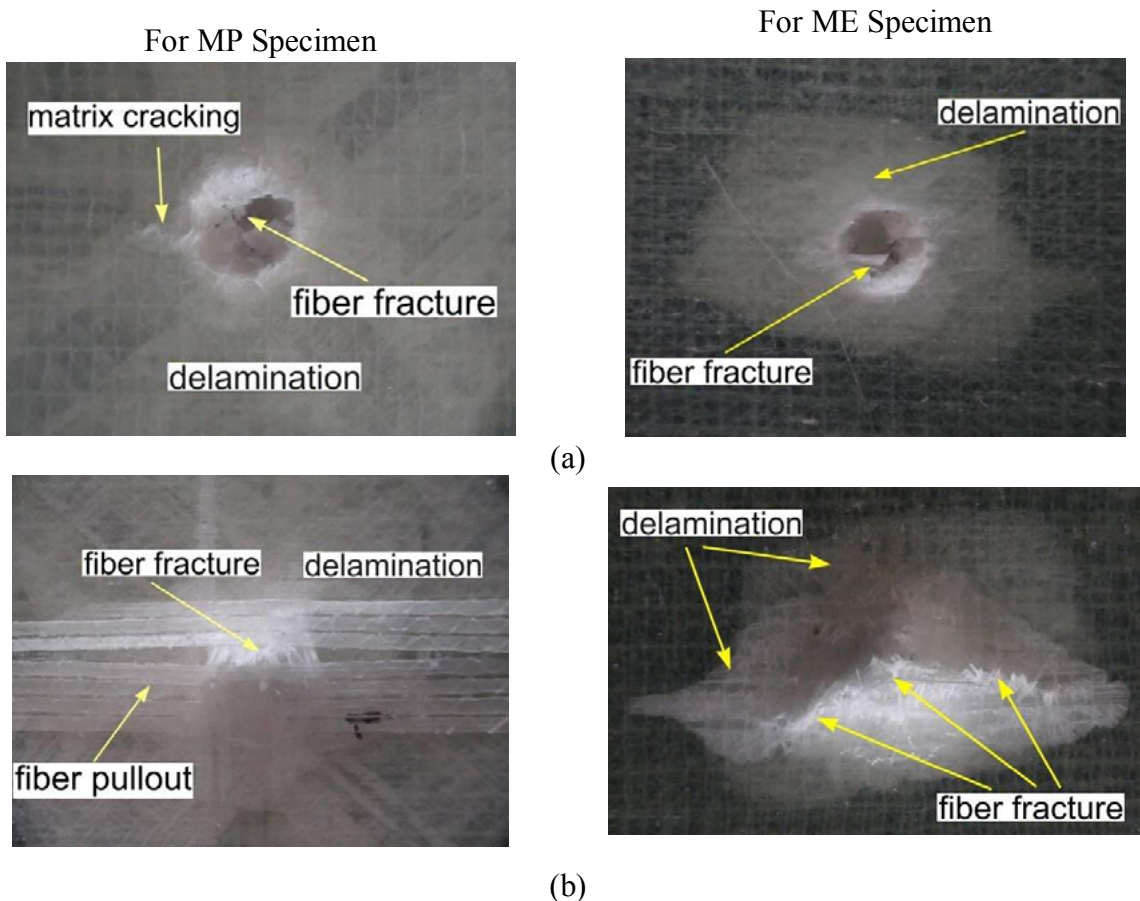
For MP Specimen   For ME Specimen

(a)

(b)

Figure 4: Damaged specimens of the MP and ME composites at penetration threshold a) impacted side and b) non-impacted side

The damage processes of impacted non-crimp fabric (NCF) composite specimens were evaluated for impacted side and non-impacted side by visual inspection, as seen in figures 4 and 5. As it can be seen from Figures 4 and 5, impact damage modes consist of matrix cracking, indentation, delaminations between adjacent layers, fiber breakages and fiber pullout. For 60J impact energy, damage modes are matrix cracking, fiber fracture and delamination. When some fibers of MP composite have fractured at impactor contact region, fibers of ME composite started to fracture in the through thickness. Shape of fiber accumulation is similar to a hill at the center of specimen, as seen figure 5(b) for MP specimen.
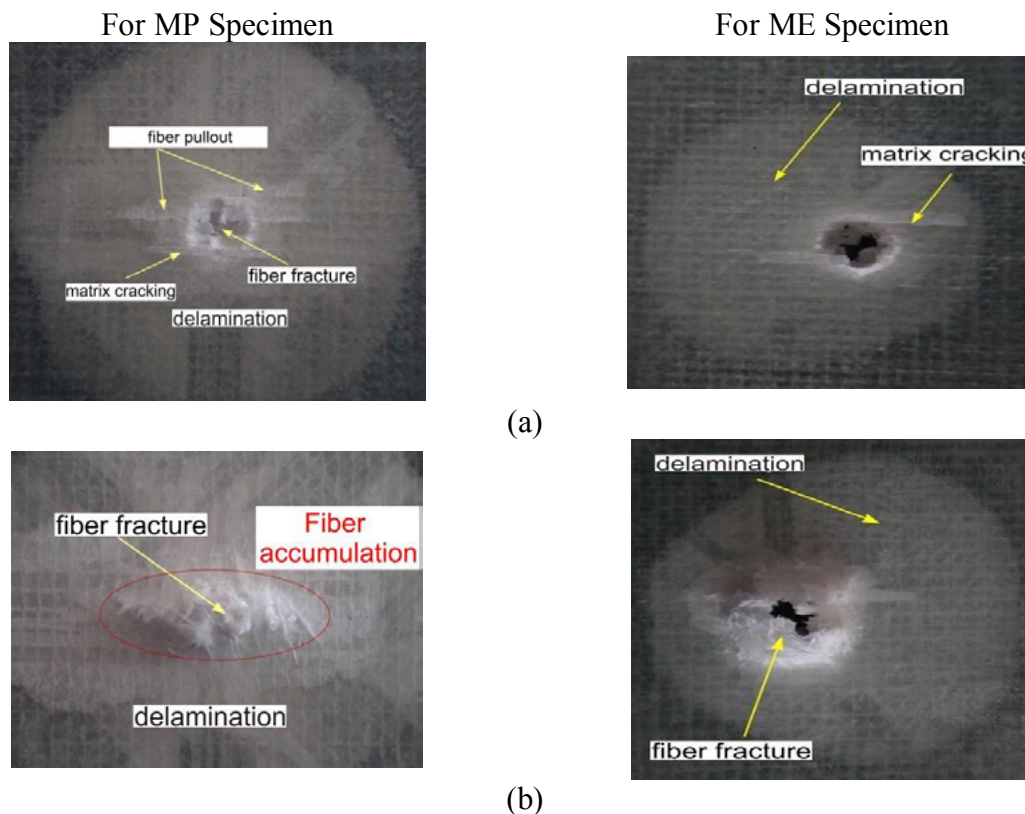
For MP Specimen   For ME Specimen

(a)

(b)

Figure 5: Damaged specimens of the MP and ME composites at penetration threshold a) impacted side and b) non-impacted side.

4   CONCLUSIONS

- Whereas MP composites absorbs slightly higher energy up to 40 J, above 50 J, ME composites absorbs energy higher than MP composites. Both composites are very close penetration and perforation thresholds.
- Up to 60 J, the maximum peak force of ME composites is approximately 10% higher than MP composites. However, the deflection of MP composites is approximately 13% higher than ME composites.
- The Hertzian failure is observed on ME composite but it is not observed until perforation threshold for MP composite.
- Up to penetration thresholds, the delamination region of MP composite is larger than

that of ME. However, the severity of damage in ME composite is more than that of MP. After the penetration threshold, the delaminations spread the rest of specimens.

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