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Investigation on Transient Impact Response of Layered Structures (English Presentation)

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Collaborating with Disaster Prevention Research Institute (DPRI), this project investigated the impact response of two layered structures, being Glass Fibre Reinforced Polymers (GFRP) panels and Laminated Glass (LG) panels. The focus herein is only limited to GFRP panels. The use of GFRP in many engineering applications has increased over the last decades because of their high strength, high stiffness, low weight, and excellent chemical and environmental resistance. However, it is well-known that these materials are susceptible to accidental impact from foreign objects because of their brittle nature, the lack of through thickness reinforcement and the relatively low inter-laminar shear strengths. The resulting impact damages can significantly reduce the strength and stability of such structures.

The impacts are often classified as low-velocity/ large mass, e.g. a dropped tool, and high-velocity/small mass, e.g. windborne debris. This implies that the velocity of the impactor determines the type of impact. This classification neglects the characteristics of the plate being hit including its mass as well as its material properties. A more relevant classification as boundary-controlled and wave-controlled impact is to be used. For boundary-controlled impact, the plate motion dominates the impact response and the entire plate is deformed during the impact; the contact force and the plate deformation are essentially in phase. In wave-controlled impact the plate deformation is localized to the region around the impact point; the contact force and plate deformation are never in phase.

The total problem of wave-controlled impact involves the so-called indentation, which is the local deformation at the impact site and simultaneous wave propagation during and after impact. While theoretical analyses of impact and wave propagation in impacted composite structures have been discussed by many investigators, the experimental investigations of wave characterization of transverse wave-controlled impact on composite panels are relatively few. Experimental tests are still necessary in order to study the indentation/wave propagation interactions as well as the effect of impactor mass, impact velocity, and composite lay-up sequences on wave propagation characteristics.

The understanding of the damage mechanisms and wave propagation characteristics of wave-controlled impact on composite structures are essential for developing improved materials. In this study, GFRP panels were impacted using three different impactor masses at velocities up to 91 m/s using a high-velocity air cannon facility of DPRI. The effect of two composite lay-up sequences, $[(0;90)]_9$ and $[(+45;-45)/(0;90)]_{4s}$ and successive impacts on panel responses were investigated. In order to study the transient response and wave propagation, data accumulation and control system of testing machine precisely gathered the dynamic strains at different points on the composite panels. A comparison based on the peak strain response and damage characteristics of the panels was conducted. Wave propagation characteristics including wave types, wave velocities, and attenuations was obtained. The variation of strain rate with time and over the panel were also studied.

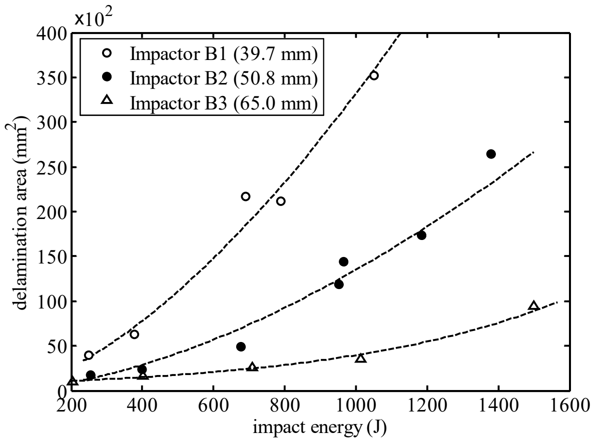

Fig. 1: Delamination areas versus impact energies

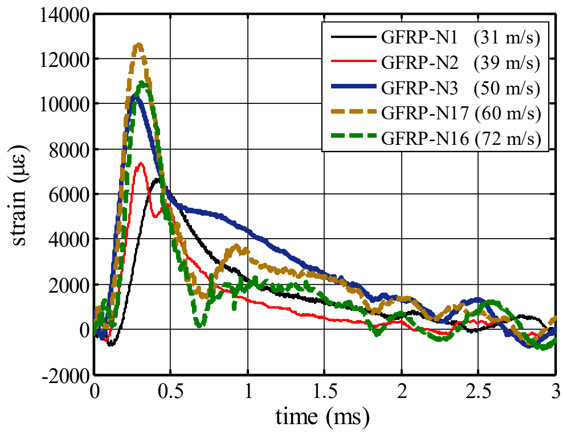

Fig. 2: Effect of impact velocity on strain response

The results showed that impactor B1 with lowest mass produced larger delamination areas than impactor B2 and B3 suggesting that impact energy is not solely adequate to define the impact incident; both the mass and velocity should be used. Figure 1 shows that the slope of the delamination area versus impact energy curve decreased with the increase of impactor mass. In other words, same level of delamination area can be produced by smaller impact energy when smaller mass was used. As shown in Fig. 2, the impact velocity was found to have a pronounced influence on the measured peak strains. In addition, the resistance to impact was found to be influenced by the composite lay-up sequence. $[(0;90)]_9$ lay-up sequence was more effective for impact resistance and absorbed a larger amount of impact energy.

The successive impacts was found to have an influence on the delamination areas, whereas it has a little effect on the perforation limit of the test panels.

As shown in Fig. 3, the pre-dominate wave was flexural traveling at isotropic velocities. Almost simultaneous with the time of major flexural wave pulse, the local indentation phase started when the panel started to locally deform forcing the material points to move toward the center of the panel and creating a stretched membrane in impact site. The flexural waves were subjected to attenuation with distance and the attenuation coefficient was found to be related to the level of damage experienced by the panel. In addition to the flexural waves, low amplitude tensile in-plane waves were observed.

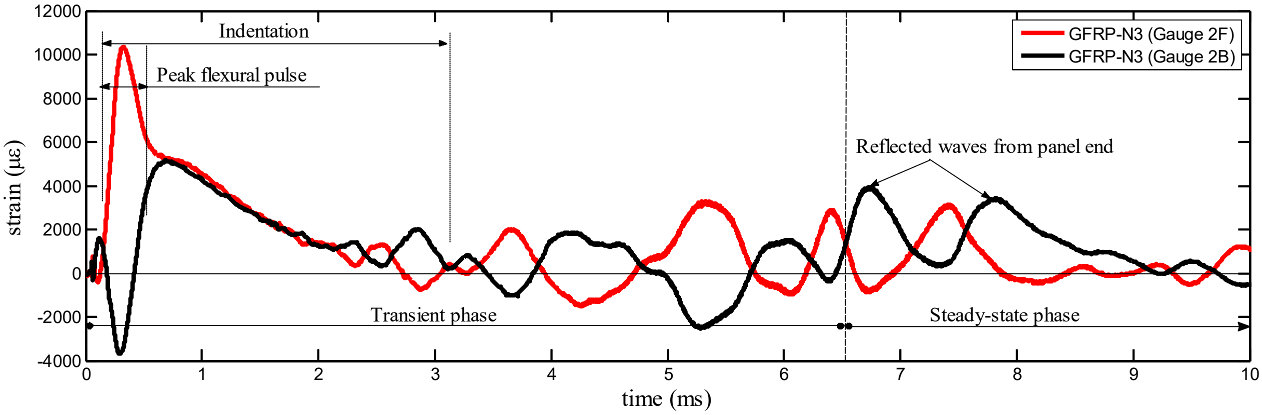

Fig. 3: Characteristics of transient response