# PENETRATION BEHAVIOR OF COMPOSITE STRUCTURES MODIFIED WITH SURFACE TREATED NANOPARTICLES

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## ABSTRACT

Fiber reinforced composites offer a wide range of functions such as vibration damping, resistance to expansion under heat cycles, corrosion and wear resistance, fatigue resistance, impact resistance, radiation and EMI shielding. With the continuous growth of composite structures in industry, government, civilian applications considerable interest has also grown in their ability to withstand impact resistance. Recent advances in nanomaterial synthesis functionalization has provided a possibility of tailorable properties and weight reduction of the structures without inhibiting the performance.

In this dissertation, glass fiber reinforced composites with alumina nanofiber modified polyester is developed and characterized. Effective exfoliation and dispersion of alumina nanofibers was observed using transmission electron microscopy (TEM) indicating effectiveness of optimized three roll mill parameters. The physical and mechanical properties at 0.25wt% loading level showed improvement in major properties regardless of surface treatment. Alumina nanofibers due to their fiber morphology had a greater effect on out-of-plane properties rather than in-plane properties. Viscosity an important property which has a tremendous influence on the processing difficulties of composite materials is characterized and it was noted that rise in viscosity in VT - Resin is just 58% as opposed to 158% at same loading level of UT - Resin. It is imperative

from the study that use of silane coupling agents to modify the surface of alumina nanofiber had tremendous effect on mechanical properties, physical properties and dispersion.

Wet layup was used as the manufacturing process with use of double drip pan for uniform wetting of glass fibers. The void fraction results revealed that surface treated alumina nanofiber resulted in reduced void content for a given alumina nanofiber loading. The 0.25wt% loading level of alumina nanofiber with surface treatment showed maximum improvement in composites. Fracture analysis of tested composites was performed using scanning electron microscopy and it was observed that, damage modes changed with untreated alumina nanofiber to vinyl silane treated alumina nanofiber. Adherence of matrix to the reinforcement is observed indicating enhanced interfacial interaction with surface treatment of alumina nanofibers. Thermal stability was improved with the addition of surface treated alumina nanofibers but nanofillers did not show a deleterious effect on glass transition temperature. The degree of cure calculations from differential scanning calorimetry scans revealed that silane treatment of alumina nanofibers improved the extent of crystallinity imparting stiffness contributing for enhanced properties.

Low velocity impact test results showed significant energy absorption through inelasticity or damage but not penetration. Damage in composites is observed to be progressive with possible matrix cracks leading to fiber matrix debonding and eventually delamination. The peak loads manifested were higher for vinyl silane treated alumina nanofiber modified composites. The initial stiffness values calculated for composites indicated existence of crack pinning, crack deflection mechanism contributing to maximum peak load and maximum energy absorption. The cone height formation after impact event was found to be more than 70% of the total displacement as observed from post damage analysis of composite samples. Ballistic impact testing results according to underwriter’s laboratory observed all the nine material systems qualifying for level 1 protection which has a maximum projectile velocity of 394m/s and 25UT, 75UT and 25VT material systems qualifying for level 6 protection level against maximum impact velocity of 469m/s.