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Thermoplastic composites for ballistic application

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Systematic studies of thermoplastic composites on ballistic impact failure and kinetic energy absorption mechanisms were examined on both semi crystalline and amorphous polymer matrix composites. By taking advantages of the nature of thermoplastic polymers, the main objectives of this research was to develop armor grade composites with thermoplastic resin matrices through an understanding of the microscopic as well as macroscopic characteristics of the composites.

In both semi crystalline neat resin and composites, the crystal formation and the degree of crystallinity of the polymer matrix were greatly influenced by processing conditions, especially the cooling rate. As the cooling rates is decreased, more perfect crystal formation and amorphous rearrangements were evident vs. cooling at higher rates. The relative degree of crystallinity of semicrystalline matrix composites was calculated using dynamic mechanical analysis (DMA). These values were in good agreement with neat resin values obtained via differential scanning calorimetry (DSC). Unfortunately the morphological perfection of the semicrystalline matrix exhibits negligible advantage of ballistic impact resistance. Failure of the composites under ballistic impact was localized and the kinetic energy absorption was low.

Amorphous polymers were also greatly influenced by processing conditions. Furthermore, amorphous polymers exhibit large processing windows in terms of processing temperature, which allows the various processing manipulations for ballistic composite fabrication. At increasing processing temperature, the glass transition temperature of the polymer and stiffness of the composite increased due to the morphological perfection and level of wetting respectively. Ballistic impact resistance was found to be inversely proportional to the stiffness of the composites. Fiber wetting characteristics and polymer morphology changes during the cooling process are considered to be major contributors to this behavior. For these reasons, samples processed at lower temperatures always gave higher energy absorption under ballistic impact.

Fabric configuration was also an important parameter influencing the ballistic performance. Relatively stiff composites, KKM2/PSU 6-2 ripstop, showed better performance with smaller fragments over the other two composites. However, KM2/SP 6-2 ripstop composites, which are less stiff that KKM2/PSU 6-2 ripstop composites, exhibited better performance with large size fragments.

Fiber breakage is the major source of kinetic energy absorption upon ballistic impact. Fiber straining is the most preferred failure mechanism of the composites for maximum kinetic energy absorption upon ballistic penetration.