Abstract

A personal body armor protects security personnel from bullets fired upon them with minimal injury. A lightweight body armor, fabricated from composite materials, does not reduce mobility and agility of its wearer while protecting them from bullets. A personal body armor generally comprises of soft armor plate and hard armor plates. The body armor's hard armor plates are used to defeat rifle-fired hard-core projectiles whereas the body armor soft armor plates are used to defeat slower-moving handgun projectiles. The scope of this work was designing a hard armor plate to defeat a 7.62 mm × 39 mm hardened steel core (HSC) projectile, fabricating the designed hard armor plates and its high-velocity impact testing.

Generally, a lightweight armor designed to defeat hard-core projectiles consists of a strike face material and a back face material. The hard strike face material is required to resist penetration of the HSC projectile in the armor. Thin high hardness steel (HHS) and boron carbide tiles (B_4C) were considered, given their high hardness, in this work as strike face materials. Various grades of ultrahigh molecular weight polyethylene (UHMWPE) fiber-reinforced composite were considered as back face material of the armor owing to their low density and high strength.

The UHMWPE fiber-reinforced composite are known to resist out-of-plane deformation originating from ballistic impact by membrane stretching and delamination. Thus, tensile strength of UHMWPE fibers directly corresponds to their ballistic performance and various grades of UHMWPE cross-ply fabric were tested to select appropriate grade of the material. A fixture was designed with an anti-rotational element to negate slipping and delamination of UHMWPE cross-ply fabric as observed by many researchers during its tensile test. The tensile strength of various

grades of UHMWPE cross-ply fabrics were successfully determined using this fixture and one grade was selected for further work.

The steels are generally used as thick plates to defeat various projectiles however, its high weight preclude its use in personal body armor application. Thus, thin HHS sheets were considered in this work. Tension tests were conducted to determine tensile strength and failure strain of HHS sheets as they directly correspond to the ballistic performance of HHS sheets. When subjected to the high-velocity impact tests the selected HHS sheet showed compression, indentation, ductile hole formation and failure. The ductile hole formation is a high energy absorbing failure mode of a steel sheet. The steel/UHMWPE composite armor was then fabricated using a compression molding machine and tested against HSC projectiles. One configuration of steel/UHMWPE composite armor was consistently able to defeat HSC projectiles. It was realized that only a projectile core eroded to certain residual length and residual mass can be effectively defeated by an armor. Experimental findings were confirmed by the numerical model which also revealed that while interacting with the HHS sheet, the core's kinetic energy decayed at a significantly higher rate.

The B_4C owing to high hardness and low density is currently most popular choice as strike face material in personal body armor applications however its higher cost and brittleness makes its use prohibitive for armed forced with lower budgets. Thus, for comparison with developed steel/UHMWPE composite armor, a B_4C/UHMWE composite armor was also developed. An array of hexagonal hot-pressed B_4C tiles were adhesively bonded to a prefabricated UHMWPE composite to manufacture B_4C/UHMWPE composite armor. When the thickness of the UHMWPE laminate was decreased while keeping the tiles similar, perforations in the armor were observed.

Thus, the thickness of backing UHMWPE is quite importance in defeating the projectile reliably. Similar to steel/UHMWPE armor case, once the core gets eroded to certain residual length and residual weight, the B_4C/UHMWE composite armor was able to defeat it. It was also observed from the numerical simulations that the damage to the tiles remain localized to a single tile when the tiles were separated by a small distance, however, the damage spreads to a larger distance once tiles were conjoined and behaved as a single unit. The study showed that ballistic protection offered by the steel/UHMWPE and the B_4C/UHMWPE composite armor is quite similar.

The developed steel/UHMWPE composite armor is significantly cheaper than B_4C /UHMWPE composite armor. Also, the steel/UHMWPE composite armor is thinner than B_4C /UHMWPE composite armor. The advantages of the steel/UHMWPE composite armor make it an attractive alternative to the B_4C /UHMWPE composite armor.