MILITARY MATERIALS

Objective Individual Combat Weapon finds targets with laser

The Objective Individual Combat Weapon (OICW) is a modular, lightweight system that can fire either 20-mm fragmentation munitions or the 5.56 mm NATO kinetic energy ammunition that is standard for the M16. The OICW's 20 mm ammunition includes a miniature electronic fuse that permits the projectile to be air-burst at the appropriate target range. The fire control includes an accurate laser range finder, ballistic computer, direct view optics, video camera, electronic compass, thermal module, and an automatic target tracker. Materials being considered for the fire-control housing are magnesium, chopped carbon fiber composites, and other composites.

To fire the 20-mm high-explosive projectile, the soldier marks the target with a red dot in his laser sights. Microprocessors inside the bullet decide how many times it must rotate before reaching the target. By means of this “advanced turns count” fuse arming technology, the high-explosive projectile speeds from the 18-inch titanium barrel to the target, and it explodes at the correct location. The projectiles are made by powder metallurgy techniques, and are hot isostatically pressed in a surface pattern that guarantees fragmentation in a predictable way. Some materials under test are tungsten powder in a titanium matrix.

To fire the 5.56 mm bullet, the soldier can detach the kinetic energy weapon. Although the barrel is only ten inches long, it is made of titanium with a stainless steel liner. Other barrel materials being considered include aluminum composites and carbon-carbon composites. It is said to be exceptionally accurate because of its cold-hammer forged rifling with a “NATO twist.” The six-lug bolt and carrier ride on steel rails enclosed with stainless steel recoil springs. Possible materials for the uni-body weapon housing include filament wound carbon and carbon fabric composites, and various other composite materials.

The OICW has the potential to replace the M16 rifle, the M203 grenade launcher, and the M4 carbine. The sighting system provides full 24 hour capability by means of its uncooled infrared sensor technology for night vision. It has an effective range of 1000 meters, with projected weight to be less than 12 pounds.

Built by Alliant Techsystems Integrated Defense Co. (www.ark.com), Hopkins, Minn., all materials in the OICW are currently being evaluated and optimized to make them lower in weight, more rugged, and easier to manufacture. The overall goal of the program is a weight of 14 lb, which includes eight rounds of the 20-mm high-explosive projectiles, and a 30-round clip of the 5.56 mm bullets.

Ceramic/composite soldier armor protects better, weighs less

New concepts in body armor that will protect soldiers against lethal small-arms and fragmenting...
threats are under development at the Army Research Laboratory, Aberdeen Proving Grounds, Md. Advanced materials such as ceramics, metal-matrix composites, and polymer-matrix composites are being combined with new processing technologies and armor designs.

One example of such a program is a system under development for a personnel armor system that can defeat a 7.62 mm armor-piercing projectile at an areal weight density of 3.5 lb/ft² or less. The effort integrates material design with experiments and with numerical simulation.

The focus for the personnel armor has been on a material consisting of ceramic tile that is backed with a fiber-reinforced polymer composite laminate. Candidate materials for the ceramic include aluminum nitride, aluminum oxide, boron carbide, and silicon carbide. Those for composite laminates include glass/polyester, aramid/phenolic, and spectra/polyurethane.

Numerical simulation is being conducted to evaluate the effects of thickness, weight, and mechanical properties of the material components on the ballistic performance of the system. For fiber-reinforced composite laminates, a cohesive zone model is being developed that will significantly improve the predictive capability of personnel armor system modeling by treating delamination and fiber breakage. Coupled with the modeling effort, high-fidelity ballistic experimentation is resulting in the elucidation of specific mechanical properties of the armor materials that are critical in defeating the 7.62 mm armor piercing threat.

For more information: Thomas Haduch, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD 21005; tel: 410/306-0799; e-mail: thaduch@arl.army.mil. Circle 157

**Ceramics, metal-matrix composites, and polymer-matrix composites are being combined with new processing technologies and armor designs.**

**Nanomaterials developed for soldier chemical protection**

Advanced materials designed to provide chemical and biological agent protection at the nanometer level are under development at the Army Research Laboratory, Aberdeen Proving Ground, Md. The direct application of these nanomaterials to the soldier's uniform has the potential of providing a low-cost, lightweight, and flexible alternative to the more burdensome charcoal suits and other protective over-garments.

Through the process of nano-encapsulation, enzyme-based nanocapsules and polymer-based nanoreactors have been demonstrated to intercept neutralize chemical and biological warfare agents. The Soldier Biological and Chemical Command (SBCCOM) has developed methods of spinning these materials into fibers that can be applied to the battle dress uniform. Though this process, very thin layers of nanocapsules and nanoreactors have been coated onto a variety of fabrics, including cotton, nylon, and the fabric in the current uniforms. The resulting protective clothing is very light and flexible to wear, and can be washed and recoated repeatedly. Potentially, these nanomaterials could be applied as a spray-on aerosol formulation.

For ballistic protection, the ARL is pursuing advances in nanoparticles. New nano-particulate processing technologies are being investigated to enable the fabrication of more efficient armor components. Ceramic materials with optimized microstructures, such as boron carbide reinforced with silicon carbide nanoparticles, can be processed into inorganic ballistically resistant components at very high mass efficiencies. Candidate ceramics, ceramic-matrix composites, and metal-matrix composites composed of nanoparticulates are being processed and characterized.

Techniques for nanoparticulate synthesis and consolidation being researched include inert-gas condensation, pulsed reactive electrode, plasma chemical synthesis, chemical vapor reaction, hot isostatic pressing, electro-consolidation, plasma-activated sintering, and plasma pressure compaction.

For more information: Thomas Haduch, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD 21005; tel: 410/306-0799; e-mail: thaduch@arl.army.mil. Circle 158

**Reactive armor technologies under development for battle tanks**

Reactive armor for battle tanks is under development at the Army Research Laboratory, Aberdeen, Md. It is designed to enhance a ground vehicle's survivability at a minimum of weight and cost. Reactive armor technology is combat proven, having been decisively applied to fielded combat vehicles such as the Bradley Fighting Vehicle System and the M60 tank. The modularity and high mass efficiency of the reactive armor has enabled these vehicles to be capable of effectively defeating shaped-charge warheads and other anti-armor threats without significant increases in weight and cost. Furthermore, extensive testing of reactive armor outfitted on current U.S. vehicles has demonstrated very low sensitivity of the reactive element.

Continued research in reactive armor technologies will provide further increases in performance at reasonable cost. New armor designs, featuring more advanced reactive and passive materials and more effective geometries, will enable the development of combat vehicles that can be tailored to meet advanced threats such as hypervelocity kinetic-energy penetrators, while being kept at acceptable gross weights. These technologies can be applied to future combat vehicle developments or as appliques to fielded combat vehicles.

- **Explosive reactive armor (ERA)** is the most effective proven technology to defeat both chemical-energy and kinetic-energy threats. ERA armors are inexpensive and easy to fabricate, and provide good multi-hit capability in modular configurations. Advanced ERA concepts are considered leap-ahead technology that can provide survivability against emerging anti-armor threats. The major challenges of applying ERA to ground combat vehicles include high indirect costs of storage, logistics, and security associated with explosive materials. It also has high integration weight burdens for platforms not designed to accept energetic armor, and subjective user preferences for passive solutions if comparable performance is possible.
The Abrams tank provides heavy armor superiority by its great mobility, firepower, and shock effect. The 1500 hp turbine engine and the special armor make it particularly suitable for attacking or defending against large concentration of heavy armor forces.

- **Self-limiting explosive reactive armor (SLERA)** places explosive materials in a configuration that limits the propagation of the explosive to a controlled area. While this results in slightly reduced performance compared to ERA, it does reduce the effects on the vehicle structure and the SLERA modules. SLERA is inexpensive and easy to fabricate, and can provide good multi-hit capability in modular configurations, but it is an unproven technology. Although SLERA currently has the same challenges of application to ground combat vehicles (primarily associated with explosive materials), it has the potential of being classified as a passive material (NATO specification.) Thus, while the energetic material in SLERA armor is not as effective as fully deployable explosives, this type of reactive armor may provide a viable option to ERA.

- **Non-explosive reactive armor (NxRA)** is a proven technology that is very effective against chemical energy munitions such as shaped-charge warheads. NxRA has gas-generating materials or other non-explosive systems as the energetic drive material in the armor mechanism. NxRA advantages over other reactive armor technologies are that it is considered passive and it is inexpensive and easy to integrate on vehicles. NxRA armors provide excellent multi-hit capability against chemical energy threats.

- **Non-energetic reactive armor (NERA)** is a proven technology that is very effective against CE munitions such as shaped-charge warheads. NERA advantages over other reactive armor technologies are that it is completely passive, and thus easy on vehicle structures. They are also inexpensive and easy to integrate on vehicles. NERA armors provide excellent multi-hit capability against CE threats.

- **Momentum transfer armor** is an advanced reactive armor technology that defeats kinetic energy threats in an efficient, compact, modular configuration. Small bars are explosively launched to impact the side of the projectile to defeat the threat through fracture, deflection, and rotation. This technology is potentially applicable as frontal and side armors on ground vehicles, and is being considered as a kinetic energy threat counter-munition option for the Army Full Spectrum Active Protection program. The challenges of applying momentum transfer armor to ground vehicles include minimizing the weight of the explosive for an optimum defeat mechanism, and achieving robustness against a wide range of threats.

- **Smart armor** is a novel reactive armor technology in which sensors and microprocessors are integrated within the armor envelope. This provides an optimized threat-defeat mechanism at a minimum of weight and space. The sensor determines the impact location, projectile-jet velocity, and diameter, while the microprocessor determines the optimum time to initiate the armor. A highly efficient armor-defeat mechanism features insensitive energetic materials and initiators for increased safety. The challenges of applying Smart Armor to ground vehicles include vehicle integration and integration with other advanced technologies, as well as threat discrimination.

For more information: Thomas Havel, Army Research Laboratory, Aberdeen Proving Grounds, MD 21005-5069; tel: 410/278-6219; e-mail: tah@arl.army.mil.

**Amphibious assault vehicle cuts weight with aluminum**

Combined mission requirements for the U.S. Marines Advanced Amphibious Assault Vehicle (AAAV) include high survivability, mobility, lethality, and reliability, while minimizing weight. To meet these requirements, a high-strength aluminum armor plate (2519-T87) was selected for the structure. The National Center for Excellence in Metalworking Technology, Johnstown, Pa., developed an improved fabrication technology and corrosion protection for the alloy, as well as data on its mechanical properties and corrosion resistance. Prior to this work, alloy 2519 had never been successfully extruded. However, the NCETM orchestrated the fabrication of AAAV-specific extrusions and established a production path with near-optimum extrusion parameters.

The NCETM also successfully demonstrated the open-die multi-axis forging that effectively broke
The Advanced Amphibious Assault Vehicle (AAA V) has over three times the speed of the Amphibious Assault Vehicle (AA V) that preceded it, and nearly twice the armor protection. It has land mobility equal to or greater than the M1A1 tank, and features crew protection against nuclear, biological, and chemical weapons. Photo courtesy U.S. Marine Corps.

down the cast structure, allowing for high properties in the final hand forging, including good strength-ductility combinations. The first hot-working simulation data was generated through the NCEMT. This information can now be used to select optimum rolling, extrusion, and forging parameters. The selected extrusion and forging para-

Magnesium alloy identified for AAA V components

After extensive evaluation of Dept. of Defense and aerospace industry practices, the NCEMT, Johnstown, Pa., has identified a low density magnesium alloy and an assembly procedure for power transfer modules and transmission housings for the AAAV.

The AAAV currently relies on a sand-cast aluminum alloys for these components. Substitution of cast magnesium could reduce weight, but magnesium alloys are anodic to most metals, especially to other structural alloys in the vehicle.

However, a sand-cast magnesium alloy, WE43A-T6, has been identified as a promising alternative, along with an appropriate fastener system, sealant compound, and coating system. As a result, a satisfactory corrosion resistance was developed in all aluminum-on-magnesium test assemblies. The WE43A-T6 alloy scratch test coupons treated with the Brush-Tagnite repair procedure did not show evidence of corrosion after three weeks of exposure.


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