Advanced Ceramic Fabrication for Lightweight Armor

Ceramic Passive Armor Protection

Army Issues and Technology Impact

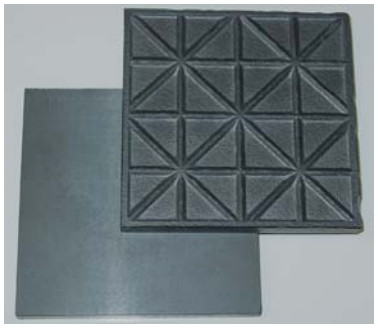
All manned platforms of the Future Combat System (FCS) must contend with asymmetrical threats and withstand first-shot, small arms (.50 Cal and below) engagements. This survivability capability must prove effective within strict weight parameters. Highly advanced ceramic fabrication methods developed at Oak Ridge National Laboratory (ORNL) reduce the weight and enhance the protection of affected/critical equipment.

Technical Approach

Ceramic tiles lower the weight of a passive armor system while improving the ability to defeat ballistic threats. Ceramic armor materials are lighter than metal, including titanium, and are 2-to-3 times harder. The hardness of the ceramic fractures the projectile, making it easier to stop small fragments. Lightweight boron carbide (B_4C) armor tiles fabricated at ORNL demonstrate superior ballistic performance compared to commercially available material.

Complex Configurations

Composite structures – Ceramic-ceramic, ceramic-metal, and ceramic-carbon composite structures can be fabricated to produce unique properties; including the potential for electromagnetic protection.
Layered structures – Layered structures of dissimilar materials are produced to create distinct internal boundaries or to form functionally graded materials.
Geometric structures – Geometric patterns, layered or formed, can be constructed for surfaces or internal interfaces.



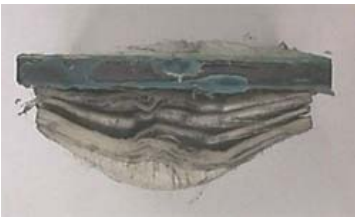
Ceramic Tile Armor w/ Geometric Surface Pattern

Past Performance

Recently, ORNL undertook the task of improving the ballistic performance of B_4C ceramic armor material. The results of direct comparison tests with two contemporary commercial suppliers demonstrated improved ballistic performance of a lightweight armor system by as much as 24% against a 7.62mm Armor Piercing (AP) threat. The results follow:

Ballistic Tests at ORNL - 7.62mm AP Threat			
B_4C Ceramic	Areal Density, psf	V_{50}, fps	V_{50} Increase
Commercial 1 (baseline)	5.26	2050	-
Commercial 2	5.20	2290	11.7%
ORNL Fine Grain	5.20	2250	9.8%
ORNL Coarse Grain	4.96	2547	24.2%

V_{50} = The velocity at which 50% of impacts are partial penetrations and 50% of impacts are complete penetrations.



Ballistic Test of ORNL Advanced Armor System

Systems Approach

Materials – ORNL develops all the materials necessary for a complete armor system. Advanced polymer matrix composite materials lighten the armor backing plate and overwrap for layered armor. The synergy of optimally combining ceramic armor tiles w/ polymer matrix composite materials is exploited.
Analysis - The CTH hydrodynamics code developed by Sandia National Laboratory optimizes the performance of the entire advanced armor system. The code analyzes a wide range of problems that involve shock wave propagation and material motion phenomena.
Test – Ballistic testing of ORNL armor systems conducted at a ballistics range in Oak Ridge is instrumental in arriving at the best systems solution to difficult armor.

ORNL Facilities & Capabilities

The Metals and Ceramics Division at ORNL boasts a long history of experience fabricating and testing structural ceramic materials. Application areas include: automotive components, gas turbine engine components, high speed cutting tools, high temperature lamp tubes, missile RADOMEs, high temperature furnace hardware, and many others. Capabilities extend from creating new ceramic compositions, to forming simple or complex shapes, to complete testing and analytical facilities for characterizing material properties.

Some Applicable Requirements from FCS Operational Requirements Document (ORD):

- **ORD 2846:** Each FCS Manned System must provide protection against penetration, blast, shock, over-pressure, fire, and thermobaric effects by providing the best combination of signature management, ballistic protection, and obscurants.
- **ORD 3237:** Each FCS Manned Platform must provide ballistic protection (structural or add-on armor) against 14.5mm; 360 degree hemispherical and 30mm, 60 degree frontal arc from greater than xx meters (Threshold). 30mm APFSDS fires from greater than xx meters, 360 hemispherical, 45mm automatic cannon from xx meters in a 60 degree frontal arc (Objective). (See Annex I)

Other Potential Utilities:

- Manned conveyances such as FCS Combat Variants (e.g. C2, R&SV) or Maneuver Variants (e.g. FR&MV, MV-E, MV-T)
- Unmanned systems with high-value payloads or critical missions (e.g. UAV)
- Blast, shock, over-pressure, frag, fire, and thermobaric effects protection
- Homeland Security and executive personnel protective systems

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