Functionally Graded and Geometrically Ordered Titanium Composite Armor Materials

Stephen D. Nunn, P. I. and Ryan R. Dehoff, Materials Science and Technology Division
Srdjan Simunovic, Computer Science and Mathematics Division

Additive manufacturing
Computational models
Advanced materials

- **Additive manufacturing was used to build complex composite armor**
- **Computer models simulate armor performance and optimize the configuration**
- **New titanium composite armor is >30% more efficient**

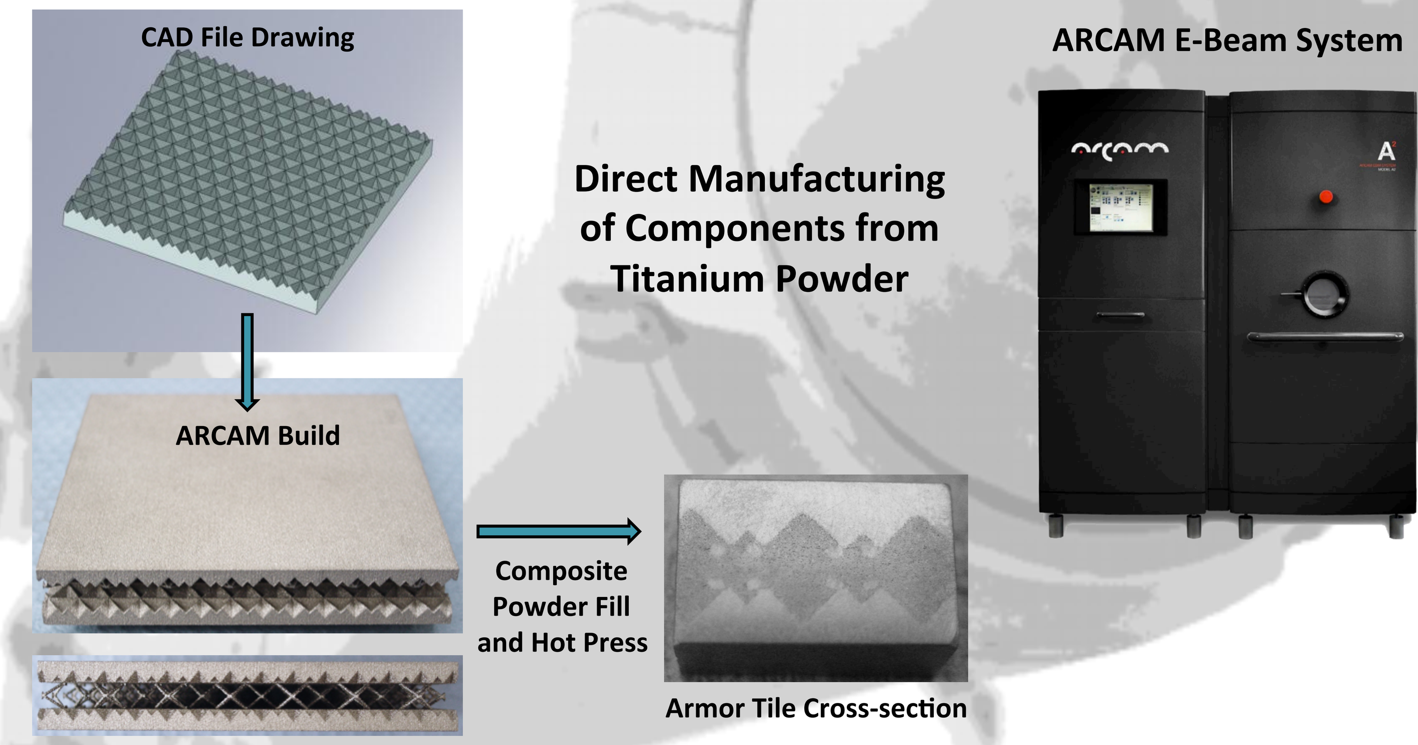
Introduction

Titanium and its alloys have many superior characteristics which make it desirable for use in defense systems. Among these are: high strength, light weight, and corrosion resistance. Ti-6Al-4V provides more efficient ballistic protection than conventional steel armor, but it is far less efficient than state-of-the-art ceramic armor. The ceramics exhibit high compressive strength, very high hardness, and light weight, but are brittle with low tensile strength.

The goal of this project was to design, fabricate, model, and test new composites of titanium and ceramic that have unique properties and performance capabilities for use in critical armor applications.

Fabrication

Advanced processing methods were used to produce armor structures with unique geometric interfaces. E-beam fusion on the ARCAM system was combined with hot pressing.



Ballistic Impact Testing

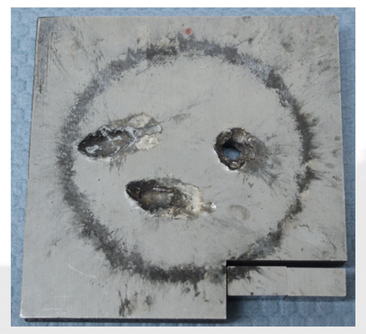
Armor tile performance was tested with 30 cal. armor piercing rounds.

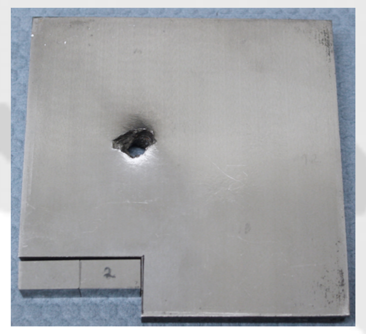
Test Site:

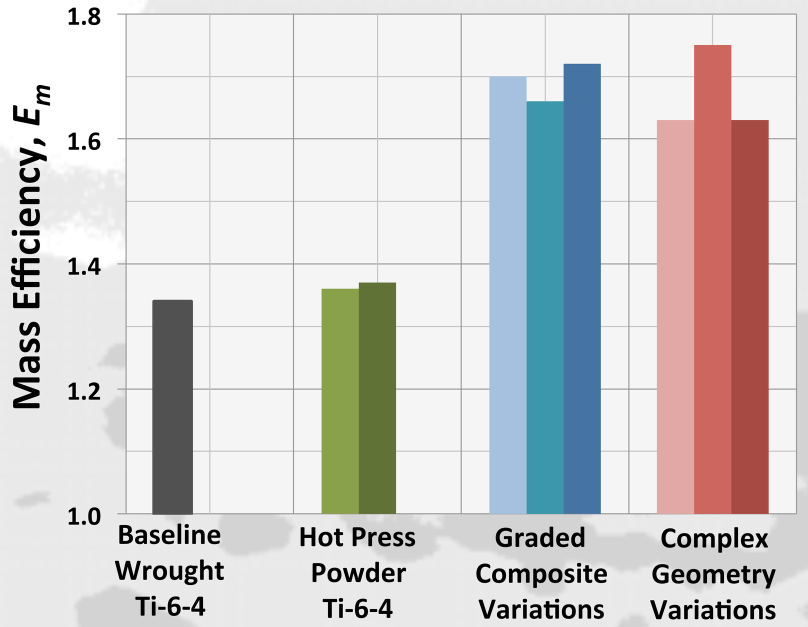

Universal receiver


Downrange view

Results:


Armor tile impact surface


Armor tile exit surface

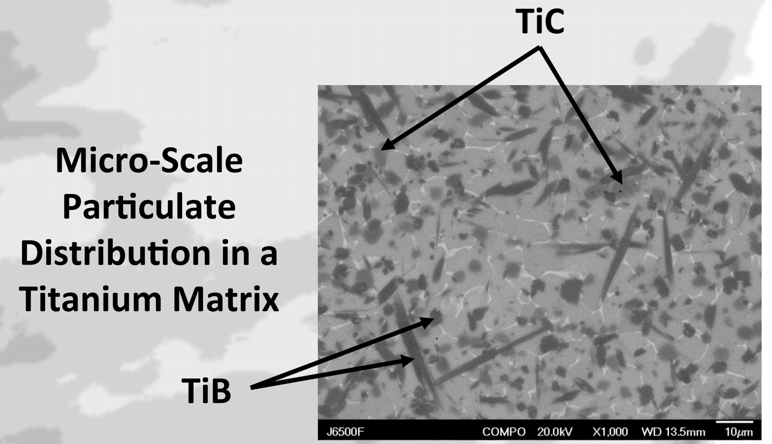


$$E_m = \frac{\text{Weight of RHA Steel}}{\text{Weight of New Armor}}$$

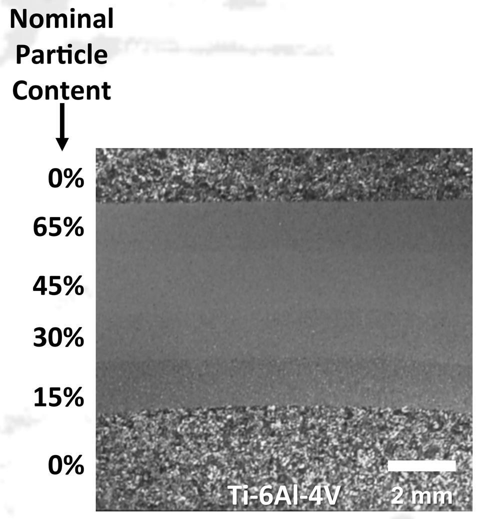
(to give equal protection)

Approach

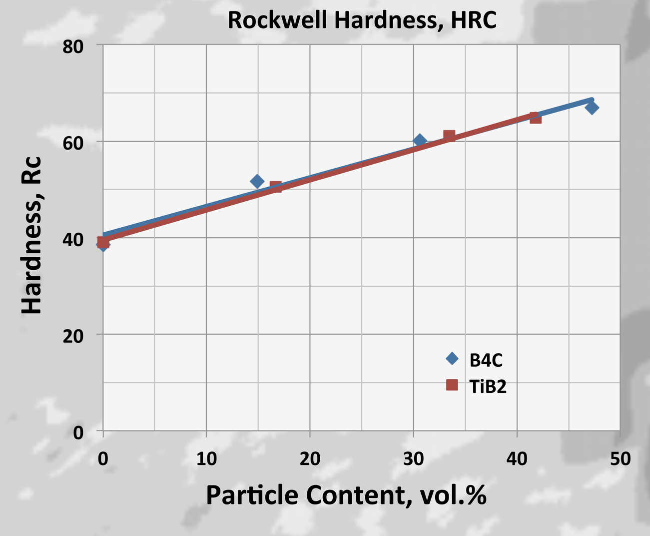
Blending of metal and ceramic powders was used to produce complex composite structures with improved properties for use as armor.

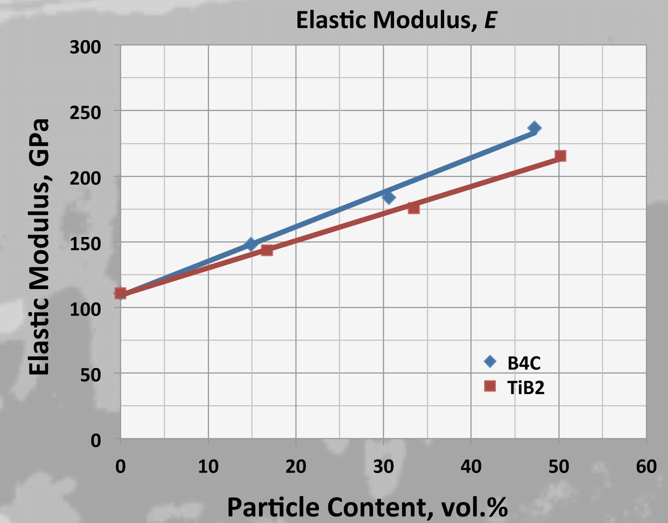


10% B_4C added to Ti-6Al-4V



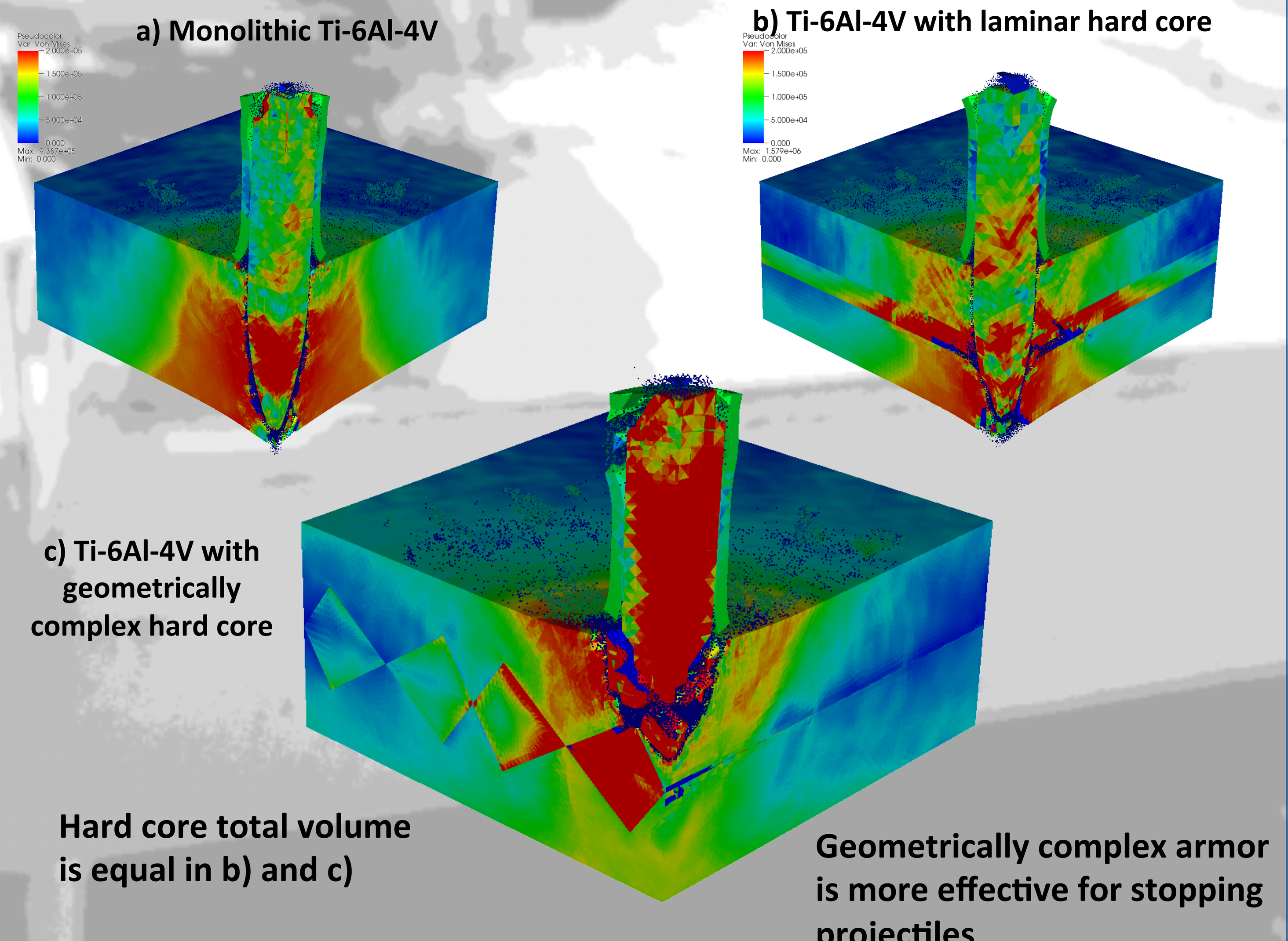
Multilayer Graded Blends





Computer Modeling

Armor materials and configurations were modeled to understand the effect of variations on stress propagation and armor failure.



0.5-inch Plate vs. 7.62mm AP M2 at 2074 ft./sec.

Summary

Advanced powder metallurgy fabrication methods, including direct manufacturing, were used to produce complex titanium/ ceramic composite structures. By using computer modeling, various composite configurations were evaluated for the effect of materials and geometry on the propagation of stress waves and resistance to damage and fracture. Composite armor tiles were tested for ballistic impact penetration resistance and an improvement in mass efficiency of >30%, from 1.34 for standard titanium to 1.75 for the composites, was demonstrated.

ORNL LDRD Fund, Global Security Directorate