LIGHTER ARMOR
FOR FUTURE GROUND VEHICLES

Lightweight armor made of titanium and other alloys is transforming military logistics.

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By the year 323 BC, Alexander the Great, King of Macedonia, had spent eight years moving his massive military force to victories across 11,250 miles. His victories were won through superior logistics, achieved by transporting troops and supplies on ships able to carry 400 tons, rather than horses carrying 200 pounds and requiring 20 pounds of food daily.

Addressing similar weight and transportation issues, the U.S. military is developing a “logistical footprint” designed to reduce the vehicle weight of its ground forces. Because 70% of combat vehicle weight is composed of structure and armor, designers are working with metals manufacturers to develop lighter-weight solutions.

Changing armor concepts

Armoring concepts have been rapidly changing since 1999, when the U.S. Department of Defense unveiled its Future Combat Systems (FCS). The new systems will transform military logistics through highly responsive land, air, and sea operations into a coordinated offensive. The United Kingdom will achieve similar types of “network-centric” logistics through its program called Future Rapid Effects System.

Finding the logistical equivalent to Alexander’s ships in its C-130 Hercules aircraft, the DoD is restricting FCS combat vehicle weight to 19 tons, a weight that permits transport in C-130 cargo planes. This smaller logistical footprint reverses a trend toward heavier armored vehicles, and effectively imposes limitations that will “compel a fundamental shift... in the armor community,” writes Retired Lt. Col. Andrew F. Krepinevich Jr., “mandating a 70% reduction in weight from the Abrams tank and 50% less internal volume to fit aboard C-130s.”

Additionally, guerrilla-style warfare tactics in Iraq are challenging armoring concepts, as combat vehicles (and tactical and support vehicles) are being exposed to 360-degree threats from rocket propelled grenades and improvised explosive devices.

Unfortunately, the lighter-weight power plant and chassis designs of tactical and support vehicles are quickly taxed by additional armor. In addition, the U.S. Revolution in Military Logistics initiatives require a 75% reduction in support and supply vehicle fuel consumption. Increased fuel efficiency is logistically critical, because fuel comprises 70% of the U.S. Army’s total weight shipped to battle zones. Support and supply vehicles make up eight of the top ten highest consumers of fuel, and the total cost for a gallon of gas in the battle zone rises to between $100 and $400. Under these conditions, lightweight armor solutions yield an immediate return on investment.

Higher mass efficiencies

To reach weight reduction goals, armor designers are turning to metals with higher mass efficiencies, represented by $Em$. The value of this number serves as a way to compare the mass efficiency of armoring materials, with rolled homogeneous armor (RHA) defined as 1. For example, dual hardness steel has an $Em$ value of 1.78, enabling it to reduce armor weight by 56% over RHA. The high $Em$ value makes dual hardness steel ideal for armored light tactical vehicles and a good candidate for armor on support and supply vehicles.

Titanium armor also has proven highly successful in several current applications. BAE Systems Land and Armaments Bradley A3/FIST variants take advantage of titanium armor. The General Dynamics Land Systems M1A2 tank commander’s hatch, GPS cover, turret blowoff panels, and armor skirts are made of titanium to reduce vehicle weight and prevent corrosion. Forged titanium is in the M2 Bradley commander’s hatch cover, and cast titanium is in the Expeditionary Fighting Vehicle sprocket and idler wheel.

Additionally, the U.S. Army Armament Research, Development and Engineering Center identifies titanium as an “excellent alternative to steel” because it is 30% lighter. Selected for its weight reduction characteristics and structural integrity, titanium gunner protection shields...
Government research institutes are working to identify key characteristics and processing techniques for armoring materials.

Titanium Rammed Graphite Castings for Military Applications
William Budd

Titanium rammed graphite castings are made in graphite molds. They consist of graphite powder, water, pitch syrup, and starch, which act as binders. Typically, the maximum size of a titanium pour is 1800 pounds, although larger castings have been produced by utilizing multiple pours and molds. Dimensionally, 50 inches in diameter by 72 inches is the maximum single pour. Walls as thin as 0.1875 inches have been produced by the rammed graphite method.

Titanium rammed graphite castings are currently melted in a vacuum arc skull furnace. In this method, consumable electrodes are melted into a water-cooled copper crucible; electrodes are either forged billet, consolidated revert, or a combination of the two. The mold assembly is placed on a table in the bottom of the furnace where the titanium can be centrifugally or statically cast, depending on the geometry of the casting and specifications that may be imposed by the customer. The furnace is sealed, a vacuum is drawn, and an arc is struck on revert material placed in the crucible, and the titanium is then melted. The molten material is poured into the mold and the mold assembly is left in the furnace under vacuum until the metal has cooled.

Cost savings from titanium rammed graphite castings for military applications can be derived through smarter utilization of the materials, the casting of near net shapes through design efficiencies, and the production of less scrap than machining.

Corrosion threats
Combat vehicles capable of surviving minefields and direct fire from enemy RPGs are still vulnerable to the same corrosion threats as poorly armored support vehicles. According to a study by NACE International, “corrosion is potentially the number one cost driver in lifecycle costs” for the DoD, at $20 billion a year. Pressing concerns over these costs have led the U.S. Deputy Secretary of Defense to appoint a Corrosion Executive, who is responsible for implementing corrosion prevention plans and procedures throughout all branches of the military.

“Corrosion impacts vital aspects of the military by reducing combat readiness, increasing maintenance costs, and reducing the morale and training time of soldiers strapped with the responsibility of ‘rust busting,’ or tending to rust prevention,” says Rich Hays, U.S. Marine Corrosion Branch Head.

Vehicles are highly susceptible to corrosion during transport, often being exposed to marine environments while aboard ships. Additionally, several U.S. Marine Corps vehicles, particularly the Expeditionary Fighting Vehicle, are expected to ford the saline waters of ocean shorelines. To develop better materials, the Office of Naval Research is conducting a six-year study by monitoring coupons located on 450 vehicles. These test results will assist in material selections that can help achieve the goal of “vehicles capable of more than 20 years of service with minimal corrosion impact.”

Steel and titanium armor
The ATI 425 titanium alloy addresses the need for a lower-cost, more-workable titanium alloy. Cost reductions are achieved by taking advantage of Class 4Mil-DTL-46077 open chemistry ranges. ATI 425 has a higher iron composition than the vanadium-rich Ti-6Al-4V, and is the only ballistic titanium amenable to cold rolling. Its high corrosion resistance in seawater helps to significantly reduce total lifecycle costs for combat vehicles.

Titanium rammed graphite castings (see sidebar), SPF, and near-net-shape parts also reduce costs. BAE Systems slashed welding hours and select armoring materials that have better corrosion resistance.

Meeting these goals is critical to fulfilling the demands placed on future vehicles. They may weigh only 20 tons, but they must still have the survivability of 60-ton tanks. Support vehicles will have hardened exteriors capable of surviving threats from gunfire and IEDs, and all vehicles should be capable of operating in varied corrosive environments while achieving lifecycles approaching 30 years.
by 50%, cut titanium structure part counts by 51%, and minimized manufacturing variations by casting the titanium in the M777A1 Howitzer.

The K12 dual hard steel is currently protecting up-armored tactical vehicles in the Iraq theater, and may provide armor to support and supply vehicles, helping reduce weight by 50% over RHA steel. K12 dual hard steel tile forms are also available for transportable add-on-armor.

Mass-efficient structural armor can be fabricated with AL 521 specialty high hard steel. The armor, with ballistic values greater than RHA, is typically placed on the upper hulls of various combat and support vehicles. AL 521 specialty high hard steel is also available in enhanced form for add-on-armor applications.

Alexander the Great’s own words best describe the current path to armor’s future, when he declared, “Upon the conduct of each depends the fate of all.” Clearly the collaboration between materials manufacturers, armor engineers, and combat vehicle designers will continue to produce lightweight, corrosion-resistant solutions to protect our warfighters.

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Resources
12. Ibid
13. Chemical composition: Ti-4Al-2.5V-1.5Fe-0.25O2