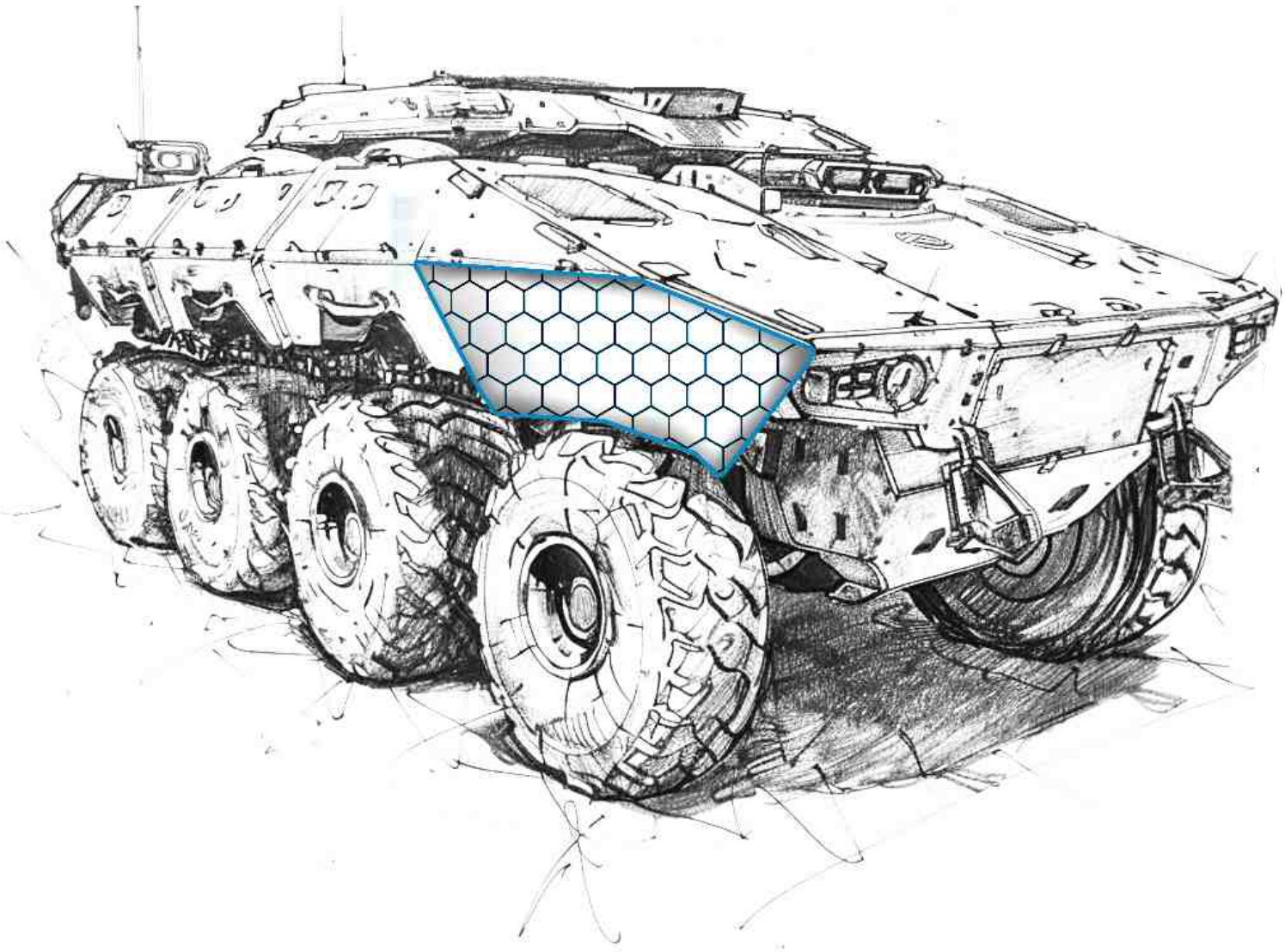
Advancements In Vehicle Armour

Unleashing the power of
ceramics for unparalleled protection



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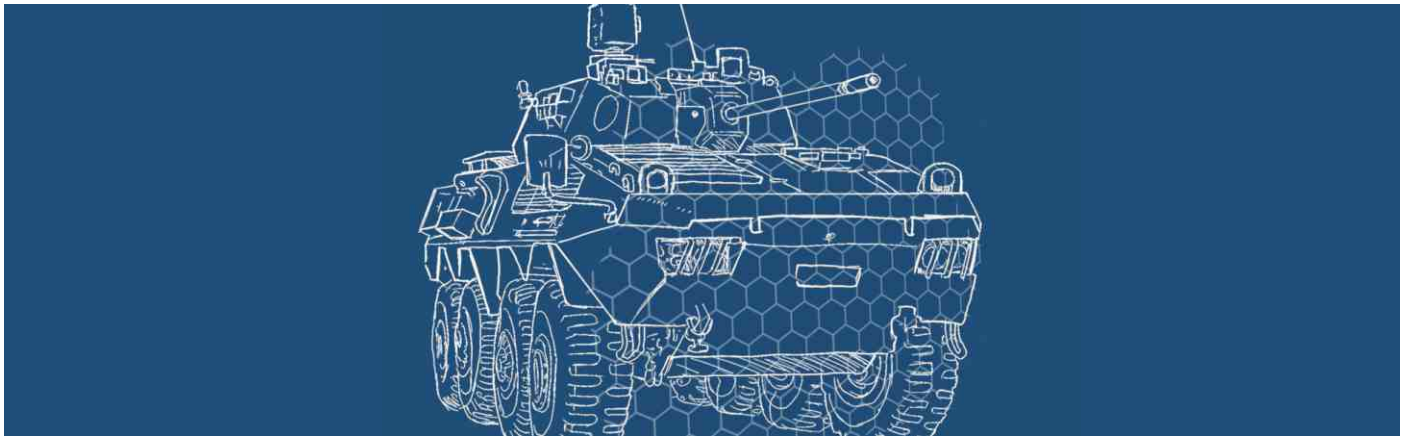

INTRODUCTION

With drastic improvements in warfare technology, weapons, artillery and explosives continue to become more lethal than ever. Wars are no longer limited to traditional battlefields. Insurgencies and asymmetric war zones are seen across the world. Persistently increasing threat levels associated with new-age wars have necessitated seismic shifts in security and defence strategies.

A crucial part of the modern-day security and defence ambit is vehicle armour. This includes specially designed and engineered protection that covers military, paramilitary, police and special civilian defence vehicles, protecting personnel and machineries from incoming threats against high velocity projectiles.

Limitations of traditional vehicle armour materials

Initially, metals like alloy steels, titanium etc. were used for armour protection. However, as threat levels evolved, these were found to be limiting not only in terms of offering sufficient protection but also restrictive to vehicle mobility. Although these metals offer limited performance, its weight makes the vehicles heavy and fuel-inefficient. Additionally, the vehicle also lacked certain properties that could help to mitigate the impact of oncoming ballistic threats or blasts.

For armour protection to be effective, it not only needs to have the right degree of hardness and strength to mitigate the threat against high-velocity projectile but also the ability to deflect its kinetic energy across a large area and absorb the shock of the impact. This demanded the search for high-performance lightweight solutions.

Manufacturers and engineers then looked at polymer-based soft armour panel to counter low-level threats. However, while polymers are lightweight, they fall short of offering adequate protection against high-level threats. This is where ceramics and hybrid composites have proved to be the most impactful.

Ceramics and composites in conjunction with metallic back-plates are cost effective to metal alloys in terms of cost to performance. This is due to the low density of the ceramic composite armour panel and hence weight is almost one-third in comparison to metallic counterparts and hence a cost-effective, performance-efficient solution in terms of protection. Their hardness and ability to shatter the oncoming projectile are far better – improving the protection level more than threefold as far as performance to weight ratio is concerned. This makes the vehicle more resilient, lighter, fuel efficient, and, hence, better performing and protected.

Overview of ceramic composites in vehicle armour applications

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Ceramic composites, typically Reaction Bonded Silicon Carbide (RBSiC), Zirconia Toughened Alumina (ZTA) or Alumina backed up with high-performance polymers, are becoming a popular choice for armour applications for vehicles. They are mounted on to a special mother plate by employing a suitable mechanism.

Ceramics like RBSiC are hard, strong, cost-effective, and absorb a large amount of kinetic energy against a high-velocity projectile. The latter property means that the kinetic energy of the incoming threat will be quickly absorbed within an optimum designed area of the ceramic armour along with back-up polymeric materials, thus reducing its extent of attack significantly. In India, ceramic composites have emerged as the material of choice for vehicle armour recently.

Ballistic protection for Light Battle Tanks

Light Battle Tanks are designed to maintain a high power-to-weight ratio. This is particularly critical to traverse mountainous terrain in remote and inaccessible areas and operate in extremely high altitudes. Their superior performance at ideal weight enables them to perform well in such conditions.

In contrast, Main Battle Tanks are neither built for easy maneouvrability, especially in such regions, nor are they equipped to navigate in such challenging conditions. As an example, due to rarefied air, tanks face several performance issues. Moreover, airlifting battle tanks to deployment areas remains one of the primary challenges.

In this scenario, weight reduction resulting in a much lighter tanks is critical to address these issues.

A definite route to achieve such significant weight reduction structurally is to replace steel with a larger number of parts engineered using advanced technical ceramics with low density and high hardness. This will not only ensure robust armouring capability against projectiles but also enable faster, more agile deployment of battle tanks, improved fuel efficiency and better tactical manoeuvrability, thanks to superior performance-to-weight ratio.

Composite armour for Wheeled Armoured Platform and other armoured vehicles

The design philosophy of Wheeled Armoured Platform (WhAP) is in consonance with the global trend which aims at achieving modularity, scalability and re-configurability to adopt the platform for variety of roles. Armour designed using advanced technical ceramics will enable highest ballistic protection without overshooting these weight restrictions. In September 2024, CUMI was awarded the Transfer of Technology by DRDO-DMRL to manufacture add-on composite armour for WhAP and other armoured vehicles.

The indigenously manufactured elastomeric add-on composite armour panels are designed using customised ceramic segments sandwiched between rubber and backed up by a metallic mother-plate which is impact-, UV- and weather-resistant. Engineered to precisely contour the vehicle, they enable superior mobility with highest levels of safety and ballistic protection.

CERAMIC SOLUTIONS FOR VEHICLE ARMOUR

Understanding the three types of vehicle protection

Vehicles are designed as per the desired protection level, which, in turn, depends on the specific defence application that the vehicle needs to fulfil. While some are designed to offer only ballistic protection, others can withstand blasts and shrapnel too.

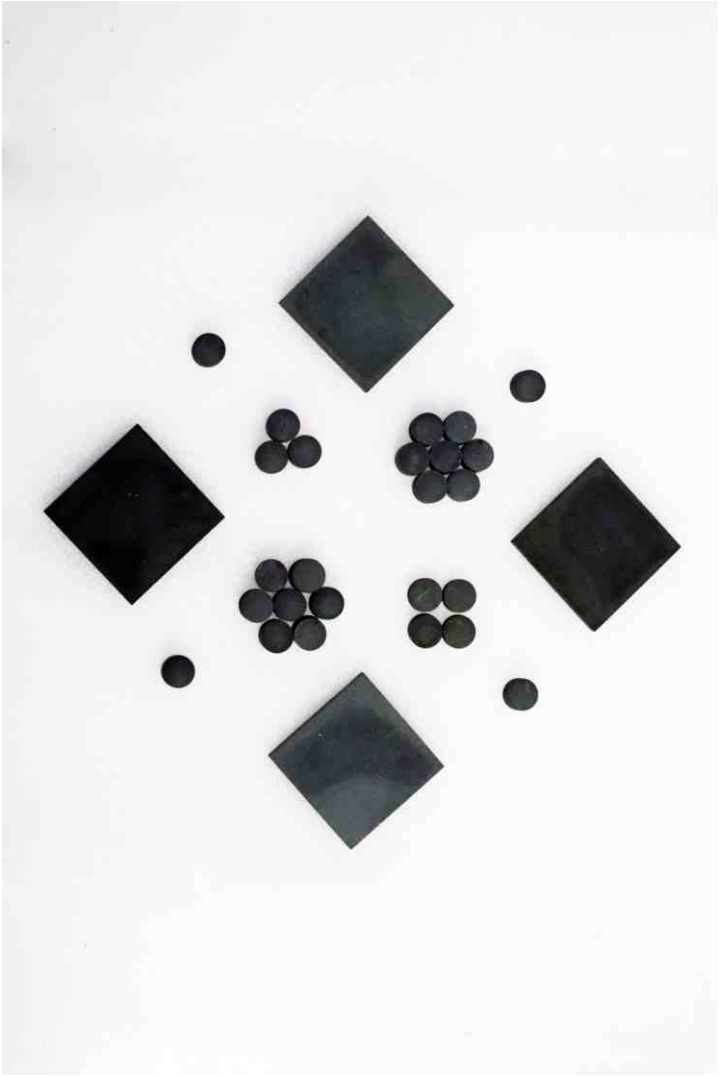
Armoured vehicles can be categorised under specific protection levels based on the specified ballistic threat level protection requirements. For ballistic testing, a predetermined number of kinetic energy threat rounds are fired at the target (armoured parts). The absence of complete perforation as well as back-face signature indicates that the desired level of protection has been achieved and is governed by the STANAG 4569 standard.

Armoured vehicles are designed to offer protection at three levels to mitigate both blast impact and shrapnel damage:

- Ballistic protection or protection against high-velocity projectiles
- Protection against blasts (explosives, not shrapnel)
- Protection against Improvised Explosive Devices (IEDs)

mitigating both blast impact and shrapnel damage. Specific vehicle types, such as those used to ferry VVIPs, such as Presidents, Prime Ministers, Ministers and Heads of the States, are suitably adapted to offer the required protection level. In addition, vehicles must be weather-resistant and UV-resistant, can endure extreme temperatures and must be well-suited to function on a specific terrain or adapt to multiple terrains (e.g., amphibious vehicles) based on specific needs.

Material of choice: Reaction Bonded Silicon Carbide (RbSiC)



Diamonds are the hardest naturally occurring mineral, with a rating of 10 on the Mohs hardness scale. Although synthetically produced, silicon carbide (SiC) comes very close at a rating of 9 next to diamond.

To take further advantage of an expansive set of properties not limited to high hardness and excellent wear resistance, high strength, and low density, it is manufactured through different processes as per the demand of the application required. Its extraordinary hardness, low density & hence lighter weight, very high specific strength along with cost efficiency has rendered protective ceramics such as RBSiC invaluable in defence and aerospace applications. Since it can be customised to a range of shapes and sizes, has high wear resistance and ensure dimensional stability.

RBSiC is commonly used in an extensive range of geometries. The fact that it can also be used to design customised polygonal plates that enable accurately lining larger, more complex surfaces as per their exact dimension makes it perfect for vehicle armour applications. This also gives it the ability to take multiple hits and effectively disperse the destructive capability of projectiles developed to penetrate and destroy armour. All these key advantages have put RBSiC at high for global vehicle armour manufacturers.

CUMI's CUMICARB_R© RBSiC products are designed to withstand extremely harsh environments while delivering outstanding performance. Engineered to be extremely strong yet light weight, ensures high reliability, CUMI's RBSiC innovations for vehicle armouring, such as rubberised ceramics, enable efficient protection of soldiers and machineries in the vehicle. CUMI is significantly increasing its RBSiC armour product manufacturing capacity to meet the needs of indigenous armoured fighting vehicles.

Defence applications and protection levels

The vehicle armour protection needed will depend on the requirements of the defence application that it is meant to serve. Different armoured vehicles come with a prerequisite for varying degrees of protection levels.

The key factors that determine the scope of a defence application are:

- Required protection level (determines the armour hardness for scattering and absorption of kinetic energy capabilities)
- Permissible density
- Permissible thickness
- Permissible weight and Cost considerations

Here's a look at the five protection levels mentioned in STANAG 4569:

- **Level 1:** requires an object of size 7.62 x 51 mm NATO Ball (Ball M80) at 30 m with velocity 833 m/s. This level also covers unexploded artillery fragmenting submunitions, hand grenades, and other small anti-personnel explosive devices detonated under vehicles.
- **Level 2:** requires an object of size 7.62 x 39 mm API BZ at 30 m with a velocity of 695 m/s. This level mentions grenade and mine blast threat from 6 kg (explosive mass) blast anti-tank mine. Here are the subdivisions: 2a: Mine explosion pressure activated under any wheel or track location 2b: Mine explosion under centre The artillery threat defined under this level must be 155 mm high explosive at 80 m.
- **Level 3:** requires an object of size 7.62 x 51 mm AP (WC core) at 30 m with a velocity of 930 m/s. Grenade and mine blast threat under Level 3 includes 8 kg (explosive mass) blast anti-tank mine and is further divided into two sublevels: 3a: Mine explosion pressure activated under any wheel or track location 3b: Mine explosion under centre The artillery threat defined under this level must be 155 mm high explosive at 60 m.
- **Level 4:** requires an object of size 14.5x114 mm AP/B32 at 200 m with a velocity of 911 m/s. The grenade and mine blast threat under this level requires a 10 kg (explosive mass) blast anti-tank mine and is divided into two sublevels: 4a: Mine explosion pressure activated under any wheel or track location 4b: Mine explosion pressure activated under centre Artillery threat defined under this level must be 155 mm high explosive at 30 m.
- **Level 5:** requires object size of 25 mm APDS-T(M791) or TLB 073 at 500 m with velocity 1258 m/s. Artillery threat under this level must be 155 mm high explosive at 25 m.

The threat specifications decide the material, design, and engineering of the vehicle armour protection. Specialised defence vehicles such as armoured cars for VVIP transport need to offer a high level of protection but look inconspicuous too – like the usual car models manufactured in factories. Such specialised civilian vehicles have a special design capable of protecting their VVIP occupants from ballistic and explosives-based threats. The armoured body together with bulletproof glass and various other defensive features and technologies convert the regular-looking vehicle into an impermeable fortress.

FUTURE OUTLOOK AND ADVANCEMENTS

Emerging trends and innovations: Exploring ceramic's role in future vehicle protection

The role of ceramics is being explored in the design of blast-resistant hulls and vehicle chassis. While earlier, these parts were made of steel, new designs, such as the 'V-shaped monocoque hull', have made it possible to use composite materials. In some recently produced composite hull designs, several advanced composites have been used to equip vehicles with lightweight protection and ensure better performance. Research indicates that the composite V-shaped hull offers enhanced protection against IED blasts.

CUMI is one of the few manufacturers of technical and high-quality ceramic products for defence applications in India. It manufactures RBSiC, high-purity Alumina, and ZTA, that offer better mechanical performance with reduced weight. CUMI also co-creates customized solutions, including advanced ceramic component offerings, for various OEMs and automotive companies for their products and processes.

Conclusion

Going forward, ceramics and composites will further emerge as a preferred option for vehicle protection. They will continue to transform and evolve to become even high-performance, efficient, lightweight, resilient, and hard-to-wear materials. Innovations will also continue to improve the efficiency of the backup material in composites, be it the p-Aramid fibre, ultra-high molecular weight polyethylene (UHMWPE), as well as high-performance resin and elastomeric materials.

Design of the ceramics & composites panel as well as mounting on the mother-plate of the vehicles and its materials would continue to evolve to become more high-performance materials. The key engineering considerations would revolve around improved performance, reduction its weight as well as cost of vehicle protection. Thus, ceramic composites will, in future, be the backbone of resilient, high-performing, lightweight defence, and special civilian vehicles protection.

Carborundum Universal Limited (CUMI) is a leading materials sciences engineering solutions provider and part of the 120-year-old Murugappa Group. As a mines-to-market company, our integrated operations include mining, power generation, fusion, manufacturing, marketing and distribution. We have over 5,500 employees worldwide who collaborate, innovate and develop high-quality material solutions and world-class services in abrasives, electro minerals, ceramics, refractories and energy storage materials, serving customers in diverse industries including engineering, fabrication, auto and auto components, infrastructure, steel, glass, power generation and distribution, mining and aerospace. CUMI has a wide geographical presence spanning six continents, exporting products to over 50 countries.

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