AN INVESTIGATION ON AUTOMATIVE TEXTILE

UmmaSaima Ikra,Mohammed Unnor Wasee Chowdhury

Abstract

This article is based on the textile materials used in automobiles or vehicles for insuring proper protection from accidental issue or bulletproofing securityissues. Transportation vehicles like car, bus, ship, aero plane and others automobiles are nowadays using this type of manufacturing protection system to ensure the safety of their users. Textile materials are playing themostvitalroleinthisissuebydevelopingthefibersrequirementinthisprocess.Mostpopular use of textile fiber in this sector are the Ballistic fabric and the Polycarbonate polymers.

TextileFiberUsedBallisticFabric

Additionally,a“ballisticweave”isaparticularlytightanddense2×2basketweave(which isthemostcommonweaveforballisticmaterial).This maximizesthefabric’stearresistanceinall directionsandextremedurability!Thelargedenieroftheindividualnylonthreadsalsoeffectively resists abrasion.

Ballistic Nylon Fabric is engineered using a veryhigh-denier nylon thread, which is typically1000Dandhigher.1680dballisticnylonand1050dballisticnylonareverypopular,and probablythemostwidelyused.Manypeopleoftenconfusetheballisticnylonfeaturebyitsdenier thread weight, but this is not entirely accurate. It’s the 2×2 basket weave which turns the thread into the material itself which is the notable differentiator.

Figure1. BallisticNylon

Our1050 Denier Ballistic material is our high tensile, durable type that is coated with polyurethane, and which makes it water repellent. Our 1680D Ballistic Nylon fabricis also used for a multitude of projects that require water repellent and mildew resistant features. The 1680D is an incredibly super-tough basket weaved synthetic material!

Itgoeswithoutsayingthatifyouareseekingahighlydurablematerialandoneofthemost strong and functional fabrics, you would be well-served by this ballistic nylon option. (1)

Ballistic nylon fabric is typically woven in a 2x2 or 2x3 basketweave pattern. The weave structure and high-denier nylon threads make ballistic nylon a strong, durable, and abrasion-resistant fabric:

	Ballistic nylon fabric
Weave	2x2 or 2x3 basketweave
Nylon threads	High-denier nylon threads, typically 1000D and higher
Properties	Strong, durable, abrasion-resistant, water repellent, mildew resistant, UV resistant
Uses	Military applications, soft-sided luggage and backpacks, and other products exposed to rugged conditions

Ballistic nylon was originally developed for military applications during World War II. It's known for its toughness and durability, and its tight weave structure makes it resistant to moisture, mildew, and UV damage. Ballistic nylon is also used in civilian applications where robustness is important.

DuPont invented nylon during World War II, and engineers continue to fine-tune the material as a fabric that is resistant to tearing and other forms of damage. The product was initially designed for military and specialized use, serving as an anti-fragmentation ballistic jacket that guards against bullets, shrapnel, and other impacts. Many layers of the fabric were laminated together to form a barrier that protects the wearer against these threats.

In the past, ballistic nylon was used for armor. However, it has largely proven ineffective in stopping bullets and is considered a particularly tough and highly functional material because it still preserves soldiers. In 1978, the military upgraded the protection to Kevlar and a more effective ceramic plate technology – technology that can stop bullets and shrapnel. In the past, military use was the largest consumer of ballistic nylon, but today it is used in many applications. While there is still an emphasis on its use in military equipment, ballistic nylon has transitioned into other products such as backpacks for work and school.

The term ballistic was popularized during the 1980s when new manufacturers entered the market and created heavy-duty luggage. Manufacturers marketed these suitcases to offer ballistic protection, though they were not bulletproof. Even though the kevlar weave is more robust, the cotton canvas still attracts customers and maintains steady popularity. In contrast, Kevlar has been used to replace it in bulletproof vests.

Used most often for duffel bags, briefcases, pet beds, workwear, chairs, backpacks, and luggage, this fabric is ideal when hauling super heavy loads. It withstands high abrasion and is UV and cold resistant with vivid, vibrant artwork. Ballistic nylon is a solid and durable material. Companies should look for ways to use this material in their products to create a product that is both lightweight and hardy. Many products are made using ballistic nylon, ranging from backpacks and luggage to wallets and cases for cell phones.

The original version of this product was made from 1050 denier high tenacity nylon yarn in a 2×2 basketweave. In addition to the actual fabric, many companies use the term “ballistic weave” to refer to any ballistic nylon fabric made with a 2×2 or 2×3 basket weave made from 840 denier and 1680 denier materials.

Ballistic Weave

Additionally, the ballistic weave is a tightly bound material that provides users with the highest tear resistance, strength, and durability. Durable nylon threads allow users to withstand even the toughest wear and tear. The material also stops bullets from penetration to be used for various applications.

What are the Different Types of Ballistic Nylon?

Ballistic nylon is a material that has been popular in the market for decades. Though its original purpose may impact resistance and durability, some of the more common uses for ballistic nylon include clothing, home decor, industrial fabrics, and luggage. With a wide variety of options on the market today, it cannot be easy to find the material that best suits your needs.

Several factors influence the durability of ballistic nylon fabric: denier count, fiber type, weave, and the fabric’s construction. Denier is the textile industry term for linear mass density, and it is the unit used to describe the thickness or weight of the material. The higher this value is, the material tends to be sturdier and more durable.

1680 Denier(11.5 oz/sqyd) , 1050 Denier(12.5 oz/sqyd), 1050 Super Ballistic (13.5 oz/sqyd)

Ballistic Nylon is a heavy-duty synthetic coated fabric, woven in a basket weave. It has a strong durability creating a long product life. It can sustain a high volume of usage with minimal evidence of abrasion, wear and tear, and fading.

- **This is a urethane-coated durable water repellent fabric with high abrasion resistance. This is an extremely strong and durable fabric used in many end products.**
- **Available only in black and 60″ wide.**
- **Stock 1680 Denier, 1050 Denier, and 1050 Denier Super**

- **Uses: luggage, tool belts, straps, jackets, chaps, duffle bags, protective covers, office furniture and much more**

https://www.canwiltextiles.com/synthetic-coated-fabrics/ballistic-nylon/

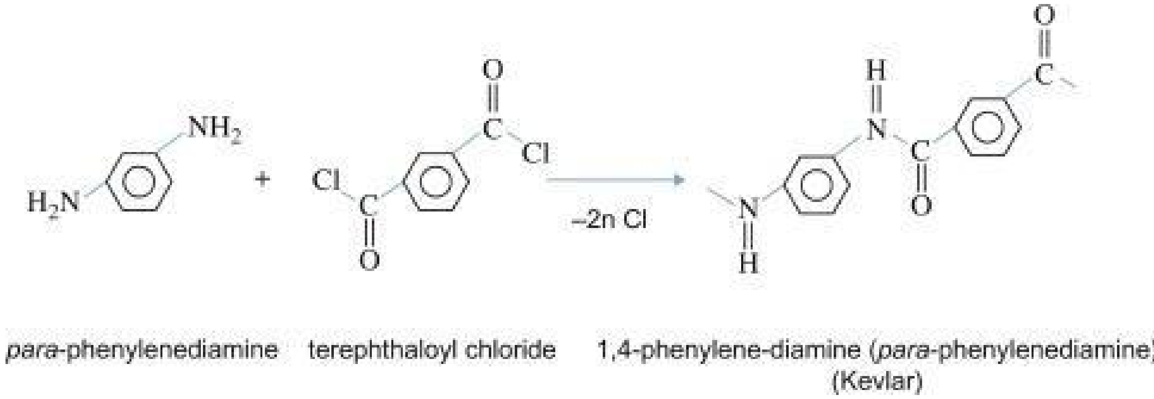
PolycarbonatePolymers

Polycarbonates(PC)areagroupofthermoplasticpolymerscontainingcarbonategroupsin their chemical structures. Polycarbonates used in engineering are strong, toughmaterials, and some grades are optically transparent. They are easily worked, molded, andthermoformed. Becauseoftheseproperties,polycarbonatesfindmanyapplications.Carbonateestershaveplanar OC(OC)$_2$ cores, which confer rigidity. The unique O=C bond is short (1.173 Å in the depicted example),whiletheC-Obondsaremoreether-like(thebonddistancesof1.326Åfortheexample depicted). Polycarbonates received their name because they are polymerscontainingcarbonategroups(−O−(C=O)−O−). A balance of useful features, including temperature resistance, impact resistanceandopticalproperties,positionspolycarbonatesbetween commodityplasticsandengineeringplastics.Polycarbonateisadurablematerial.Althoughithashighim pact- resistance,ithaslowscratch-resistance.Therefore,ahardcoatingisappliedtopolycarbonate eyewearlensesandpolycarbonateexteriorautomotivecomponents.The characteristics of polycarbonate compare to those of polymethyl methacrylate(PMMA, acrylic), butpolycarbonateisstrongerandwillholduplongertoextremetemperature.Thermallyprocessed material is usually totally amorphous,[7] and as a result is highlytransparent tovisible light, with better light transmission than many kinds of glass.

Polycarbonate has a glass transition temperature of about 147°C (297°F),[8]so it softens gradually above this point and flows above about 155 °C (311°F).[9]Tools must be held at high temperatures,generallyabove80 °C(176°F)tomakestrain-freeandstress-freeproducts. Lowmolecular mass grades areeasier to mold than higher grades, but their strength is lower as a result.Thetoughestgrades havethehighestmolecularmass,butaremore difficultto process. (2)

KEVLAR

PolymercompositescanuseKevlarasareinforcementinsteadofglassorcarbonfiber.The aromaticnylonfiber,Kevlar,canbecombinedwith polyamides(nylon),polyesters, epoxies,polypropylene, orPEEK. The plastics can be combined with the Kevlar and then compression molded into a plastic part. The chemistry behind the process of making Kevlar is shown infigure 2. Kevlar is produced with a reaction of 1,4-phenylene-diamine (*para*-phenylenediamine) and terephthaloyl chloride in acondensation reaction yieldinghydrochloricacid as a by-product and 1,4-phenylene-diamine (*para*-phenylenediamine) (Kevlar). (3)



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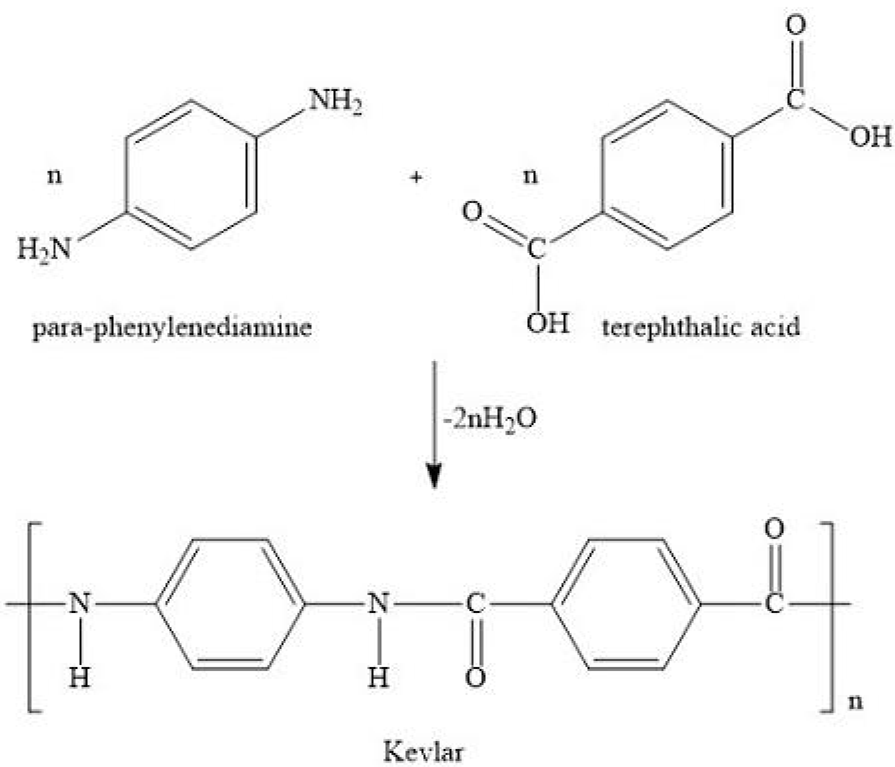


Figure2. ChemicalProcessofKevlar Production

Table1. KevlarProperties(HalladandBanapurmath,2018)

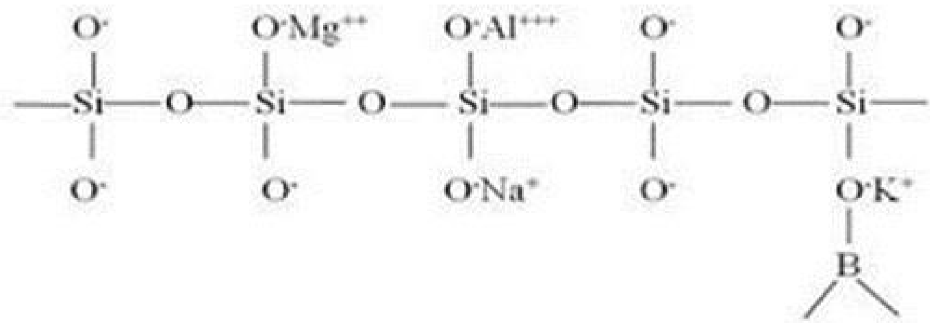
Grade	Density (g/cm^3)	TensileModulus (GPa)	TensileStrength (GPa)	Elongation (%)
29	1.44	83	2.92	3.5
49	1.44	124	3.45	2.9
149	1.47	179	3.60	1.5

GlassFiber

There are a lot of interesting ingredients that go into the successful creation of fiberglass. It'safantasticexampleofacompositematerial.Theblendusuallyfeaturescertainmeasurements of the following materials: limestone, silica sand, soda ash, borax, magnesite, nepheline syenite, feldspar, kaolin clay, and alumina. Glass is also essential, and resin is often thrown into the mix, too.

Afteryouhavetherightweightandmeasurementsofeachingredient,you'llblendthemandplace themintothefurnaceformelting.Thisprocesscreatesmoltenglassthatcanbecutintofibersand wound up and lengthened into long filaments or chopped up and used in sheets, insulation, or coatings.

Once it's created, fiberglass typically has a density of between 2.4 and 2.76 g/cm3. The time it takestomanufacturewilldependonthetypeoffiberglassyou'reusing,whatapplicationit'sbeing used for, how long it takes to cure, and the quantity being made. (4)


O·
O·Mg++
O·Al+++
O·
O·
Si
O
Si
O
Si
O
Si
O
Si
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O·
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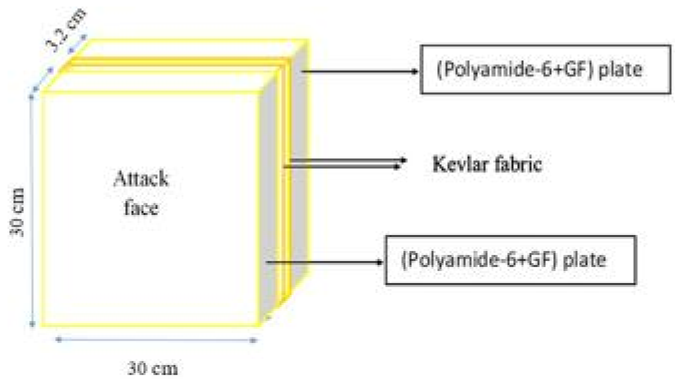
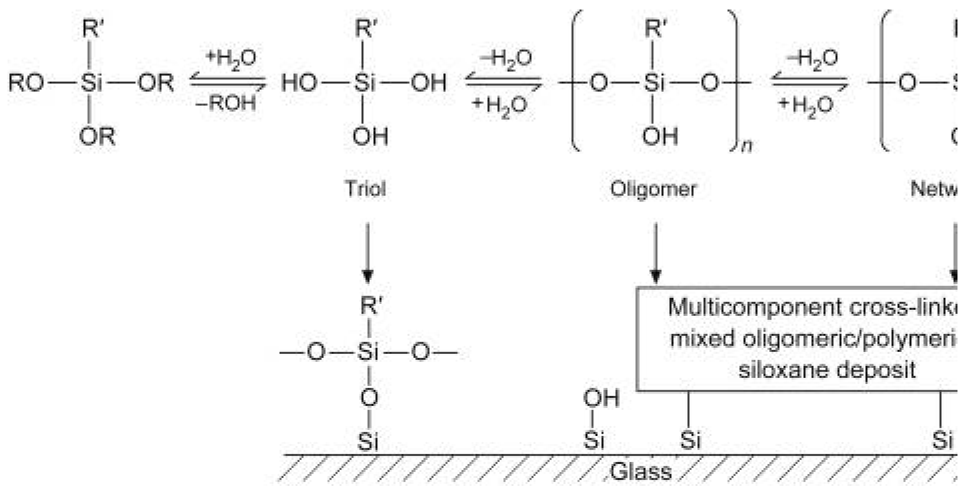
O·
O·K+
B


3.2 cm
(Polyamide-6+GF) plate
Attack
face
Kevlar fabric
30 cm
(Polyamide-6+GF) plate
30 cm


RO—Si—OR
+H2O
−ROH
HO—Si—OH
−H2O
+H2O
Triol
Oligomer
Multicomponent cross-link
mixed oligomeric/polymeri
siloxane deposit
Glass

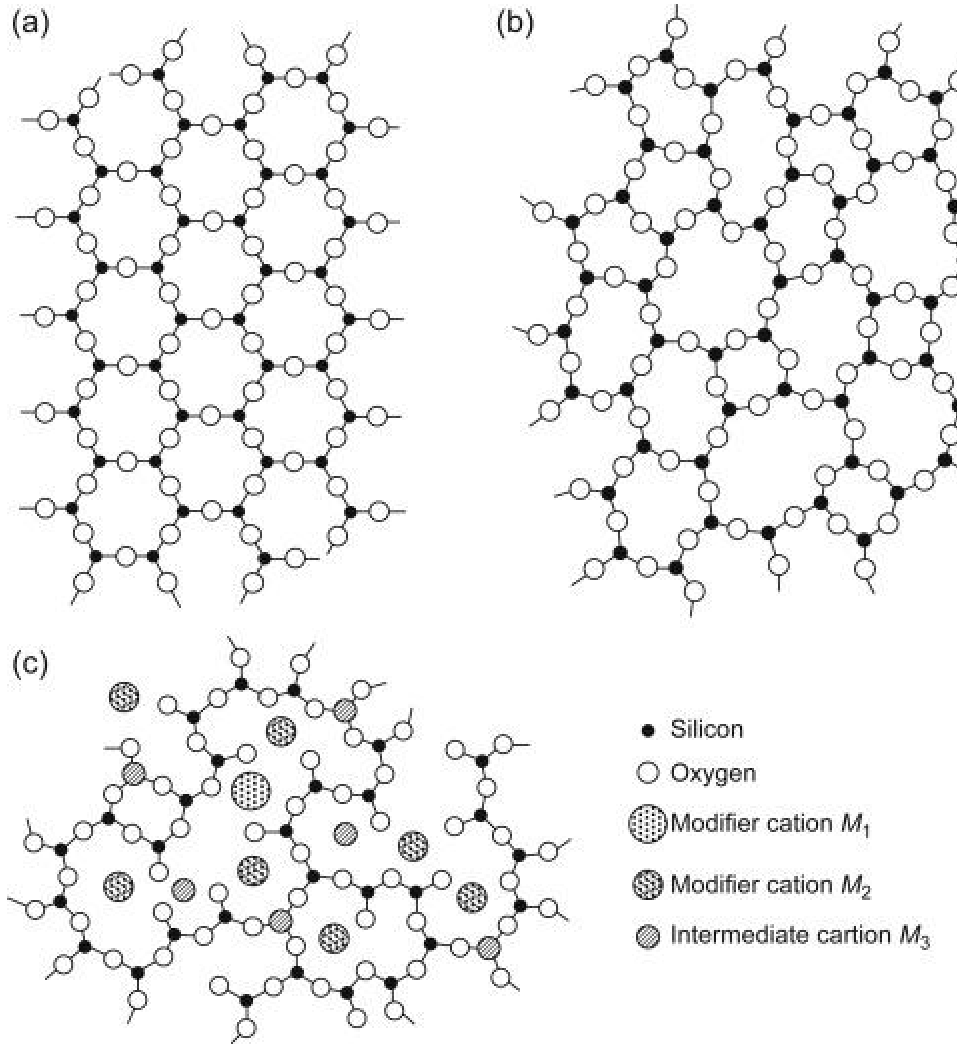


Figure3. MolecularStructureofFiberGlass

Table2. MechanicalPropertiesofFiberglass

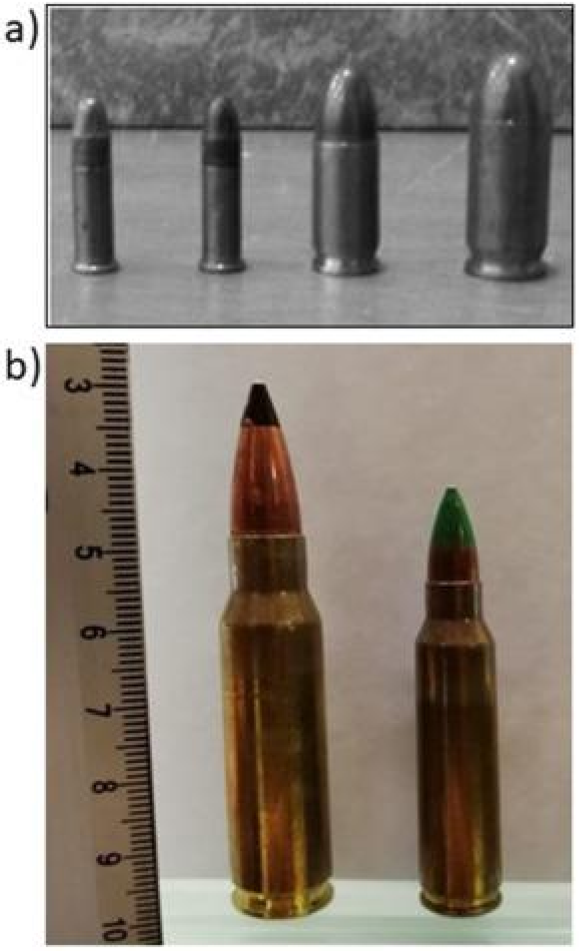
Physical Property	Density (g/cm^3)	Tensile Strength (GPa)	Young's Modulus (GPa)	Elongation	Coefficientof Thermal Expansion, x10^{-7}(°C)
E-glass	2.58	3.445	72.3	4.8	54
C-glass	2.52	3.31	68.9	4.8	63
S2-glass	2.46	4.89	86.9	5.7	16
A-glass	2.44	3.31	68.9	4.8	73
D-glass	2.11–2.14	2.412	51.7	4.6	25
R-glass	2.54	4.135	85.5	4.8	33
EGR-glass	2.72	3.445	80.3	4.8	59
ARglass	2.7	3.241	73.1	4.4	65

Ballistic tests

Ballistic tests with six different firearms were performed in a Mexican army certified laboratory under the NIJ standard-0101.04 [26]. The short (0.22″, 0.25″ and 0.45″ caliber) and long (9 mm, 5.56 mm and 7.62 mm caliber) weapons were fired at a distance of 5 m and 15 m, respectively, with an incidence angle of less than five degrees. A ballistic chronograph (CF-200 model) was used to measure the bullet speed. The shots were recorded using a 33,000 frames per second high-speed video recording camera (I-SPEED, model, 0400,548 series, OLYMPUS). The firearms and bullets characteristics are shown in Table 1 and Fig. 2.

Table 1. Characteristics of the firearms and bullets.

Experiment number	Gunpowder weight (g)	Number of gunpowder grains	Weapon type
1	2.54	40	Automatic gun 0.22″
2	3.24	–	Automatic gun 0.25″
3	11.60	–	Automatic gun 0.45″
4	8.16	124	9 mm, Parabellum
5	4.01	–	5.56 mm, M–16 Rifle
6	9.70	148	7.62 mm, Fusil G-3



1. Download: Download high-res image (264KB)
2. Download: Download full-size image

Fig. 2. Bullets used for the ballistic tests. Left to right: (a) cartridges 0.22″, 0.25″, 0.45″ and 9 mm caliber, and (b) cartridges 7.62 mm and 5.56 mm caliber.

The manufactured (PA6+GF)-Kevlar ballistic panel was fixed at its four corners on a test bench and rigidly secured in a plane perpendicular to the fireline, so that it did not move or displace, according to the NOM-142-SCF1-2000 standard procedure [29].

The temperature and humidity conditions during the tests were maintained at 22 ± 3 °C and 65 ± 4% relative humidity (RH). The ballistic panel was placed far from the barrel, at a distance of 5 m (short-weapons) and 15 m (long-weapons).

The ballistic tests were carried out in the absence of wind. The shot impact was made on the panels attack face shown in Fig. 1. Three shots of each bullet caliber were made at the center of the armor panel in a triangular shape, each other spaced at a center-to- center distance of 10 ± 3 cm (short-weapons) and 12 ± 4 cm (long-weapons). After each shot, the panel performance against bullet penetration was evaluated measuring the penetration depth employing a depth micrometer (0–30 mm, 29,525 model, KLE401 series MITUTOYO), with an accuracy of 0.01 mm. The impact energy (J) was calculated with Eq. (1) and results are reported in Table 3.

$$e=\frac{m*v^2}{2} \quad (1)$$

where:

Table 2. Mechanical properties of the polyamide 6 and composite (PA6 + GF).

Material	Charpy impact energy (kJ/m²)	UTS MPa
Polyamide 6 (PA6)	2.52	37.31
(PA6-GF) composite	9.53	91.17
Aramid fabric	–	170.72
(PA6-GF) + Aramid	–	264.99

Table 3. Impact results.

Caliber Weapon	Ogive (g)	Average Bullet speed (m/s)	Average impact energy (J)	Penetration depth (mm)	Observations	
.22″	2.54	386	189.49	–	Valid impact	The bullet did not penetrate
.25″	3.24	232	87.28	–	Valid impact	The bullet did not penetrate
.45″	11.60	287	480.39	–	Valid impact	The bullet did not penetrate
9 mm	8.16	354	511.99	6.05; 5.82; 5.45	Valid impact	Partial penetration without side-to-side drilling
5.56 mm	4.01	882	1561.12	9.53; 9.30	Valid impact	Partial penetration (spalling)
7.62 mm	9.7	887	3816.19	10.83; 12.72	Valid impact	Partial penetration (spalling)

e = energy (J)
m = mass (kg)
v = speed (m/s)

The surface morphology and GF dispersion changes of the composite polymer before and after the ballistic tests were observed in a Scanning Electron Microscope (JSM 6490 L.V. model, JEOL).

https://www.sciencedirect.com/science/article/pii/S223878542100315X

VehicleCustomizedMaterials

When looking for materials to bulletproof your vehicle, only a few are up to the task that can actuallybe thin enough to fit inside a vehicle and stop thedamage, namely, fabric consisting of ballistic nylon, steel, polymer, and armored glass.

Theballistic glassis definitelynot your typical dinnerware but rather a specialized bulletproof to withstand greater compression, pressure when bullets would hit the vehicle. The windows of the vehicle are the most vulnerable part if you are ever to be attacked. So the usual formation to get anyprotectionagainstthatisanouterlayerof bulletresistantglasswithaninnerlayerofpolymer plastic.

With the actual process, different parts of the car have different requirements. You cannot armor thetirethesamewayasthewindowofthevehicleforobviousreasons.Hereisapartbypartguide to armoring or bulletproofing your vehicle:

Door

This is probably one of the most accessible parts of the vehicle. Since the vehicle becomes substantiallyheavyafterbeingarmored, youwouldneed aheavyhingeforsupport.Asteelhinge with at least 3 clasps is good enough of a start.

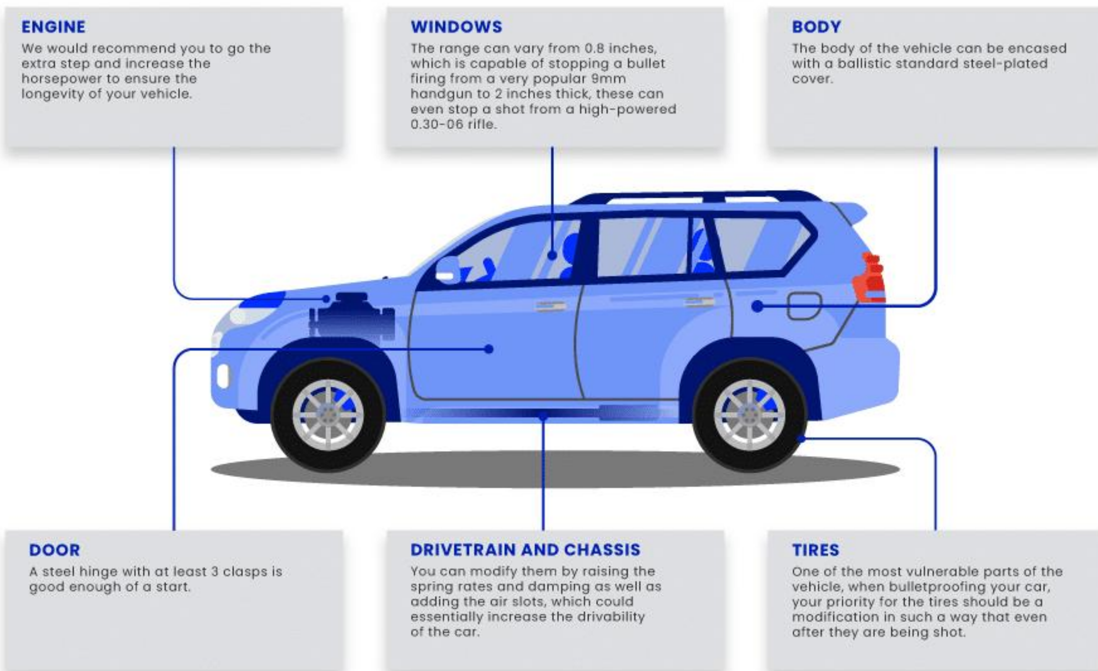


Figure 4. Bullet-proofingofCar

Body

The body of the vehicle can be encased with a ballistic standard steel-plated cover. The inside of the ceiling and the floors can also be encased with ballistic fabrics. The front could be extended to increase the shock bumper. They are effective shock absorbers, which can help to absorbenergyduringanaccidentorcombat.However,theseadditionscanbeasinconspicuousas possible to let the attacker be unaware of the extra protection.

Tires

Oneofthemostvulnerablepartsofthevehicle,youmayhavewatchedinmoviesifnotin real-life situations that people tend to shoot first at your tire to slow down and inevitably engage incombatlater.AccordingtothewebsiteTorquewrenchcenter.comwhenbulletproofingyourcar, your priority for the tires should be a modification in such a way that even after they are being shot,theyareabletorollenoughtimestogetawayfromthescene.Biggerandmorearmoredcars can use an onboard tire pressure control and sealing system while the smaller cars can rely on a composite flat run tire as the regular ones cannot handle gunshots.

Windows

As previously mentioned, bulletproofing or armoring the windows, which encompass a large fraction of your vehicle, is an important step when bulletproofing your car. Just a thicker version of safety glass is not enough when you want a fully armored vehicle.

Usually,these canbreak underthespecificcompressionfrom bulletscomingathighspeed.They arenotevenmadetowithstandagainstmostofthehigh-profilecarrobberies.Tobulletproofyour windows,youmustsandwichthemwithpolycarbonatepolymerontheinsideandleadedglasson the outside. The thinner leader glass has a diameter of 0.8 inches, which is capable of stopping a bullet firing from a very popular 9mm handgun.

However,ifyouarenotsatisfiedwiththat,youcanalsochoosethethickestbulletproofshielding, whichisabout2inchesthick.Thesecanevenstopashotfromahigh-powered0.30-06rifle,which is one of the top graded combat weapons.

DrivetrainandChassis

There is no point in armoring your vehicle if, at the end of the day, it cannot run.When youarmororbulletproofavehicle,youaddinalotofextraweighttothevehicle.Eventhelightest armoringcan add up to a substantial 300 pounds on thevehicleas extraweight. If you go all out, youcanexpectaminimumof1,000pluspoundsofadditionalweighttothevehicle.Withallthese extraweights,thedrivabilityofyourvehiclemaydecreaseifyoudon’tmodifythechassisandthe drivetrain according to the law of proportionality. Typically, you can modify them by raising the spring rates and damping as well as adding the air slots. That could essentially increase the drivability of the car.

Engine

While most of the present-age sedans have enough horsepower to pull through additional weightfromthearmor,itstillisnecessarytocheckifyourvehicle’senginecanactuallycopewith it.However,keepinmindthatthemoreofyourhorsepowerthevehiclehas,italsoconsumesmore gas.So,if youliveinaresource-scarcearea,and youcansee yourcarcan handletheaddedload, it is recommended that you don’t modify the engines any further. Most of theSUVs and their enginescanholdadditionalweightinthecar.Butifyoudon’thaveanyqualmsabouttheusageof gas, we would recommend you to go the extra step and increase the horsepower to ensure the longevity of your vehicle.

LiteralBulletproofing

There are many reasons why you might want to bulletproof your car. You could live in a bad neighborhood, or you maybepreparingto takeatrip through adangerousregion. Youmight justsleepbetteratnightknowingthatyourcarisprotectedoutonthestreets.Cartheftdidspike across the United States between January and May of 2020, as more cars were lining the streets unused.Apparently,vehiclelarceniesincreasedby63%inNewYorkaloneduringthistime.This isjustcauseforthinkingmoreseriouslyaboutthegeneralsecurityof yourcar.Notonlyaremore people investing in security systems, but another way to protect your car is to armor it. You can literally bulletproof your car by focusing on the following key features. (5)

AircraftCabinFlooringandInteriors

Aircraftcabinfloors,overheadbinsandbulkheadsbuiltwith DuPont™Kevlar®honeycomb cores have helped in weight savings for aircraft manufacturers. In addition to the lighter weight, honeycomb has very low electrical conductivity and high fire resistance, which helps contribute to addressing the safety standards the industry demands. The superior thermal and sound insulation also contribute to passenger comfort.

LandingGear Doors

Kevlar®honeycombs help designers produce landing gear doors that are strong and light to allow for delivering more efficient aircraft.

Wingboxesandcontrolsurfaces

Thelightweight,lackofgalvaniccorrosion,andoverallstrengththatKevlar®honeycombs helpprovideforwing-to-bodyfairingsandcontrolsurfacesmakeitsuperiortotheheavier,weaker and corrosion-susceptible aluminum core that has been used in the past.

Filament-woundpressurebottles

Bottles containing pressurized oxygen (or other gases) on airplanes use molded casings made of Kevlar®filament to help reduce the overall weight of the aircraft. An ordinary alloy-encased bottle can suffer catastrophic failure, releasing metal fragments into the aircraft at high velocity,whereasabottleusingacasingmadeofKevlar®mayhelpriskductilefailure–rupturing, rather than disintegrating – which does not result in fragmentation.

Engine nacelles

The nacelles that surround jet engines must contend with thrust, lift and vibration forces. Manufacturers choose to use Kevlar®honeycomb core structures in engine nacelles because it is far stronger and lighter than earlier designs with an aluminum core.

Enginecontainmentrings

Many jet engine manufacturers add a protective layer of Kevlar®fabric inside the engine cowl to help catch errant fan blades or massive broken parts flung outward by the engine's centrifugal force, thus potentially preventing them from damaging the wing or the cabin.

Aircrafttires

Landingandtakeoffcycles,frictionandrapidchangesintemperaturepushaircrafttiresto their stress limits. Tires reinforced with Kevlar®brand aramid fiber help provide enhanced toughness and thermal stability.

Spacecraft

The alloy cores that historically predominated helicopter rotor blade designs are giving way to composites, of which honeycomb core made of Nomex®or Kevlar®is proving to be a material of choice. Modern helicopters are redefining efficiency and performance with lighter, stiffer rotor blades made of Kevlar®.

Spacecraft

Kevlar®fiber has proven that it is strong enough to survive the extreme forces and temperature fluctuationsofspacetravel.WhentheMarsPathfinderlandedonthesurfaceofMars, Kevlar®fiberreinforcedtheinflatablelandingcushions–andtheropesthatsecuredthem–helping thePathfindertocompleteits40-million-milejourneyfullyintactandreadytoexploretheplanet's surface.Kevlar®isusedincommunicationssatellites,andalsointhespaceshuttle,tohelpprotect against impact from orbital debris. (6)

BallisticandBlastProtectionforNavalandMarineCraft

ASL GRP provide tailor-made protection kits for your vessel or high-speed marine craft. Full threat assessments andperformance requirements are always taken into account when designing your protection. Download ASL GRP's Marine Protection brochure here.

OffshorePatrolVesselsandCrewBoats

ASLGRPofferscompleteprojectmanagementforthedesign,manufactureandintegration of armor protection solutions for naval, crew boats and offshore patrol vessels.
We can supply add-on armor kits to protectyour vessel in a hostile situation, while taking intoaccount weight and performance requirements. Commonly protected areas include:

- Wheelhouseandbridge deck
- Engineroom
- On-boardarmories
- Saferooms

Suggestedproductsfornavalandcrewboat protection:

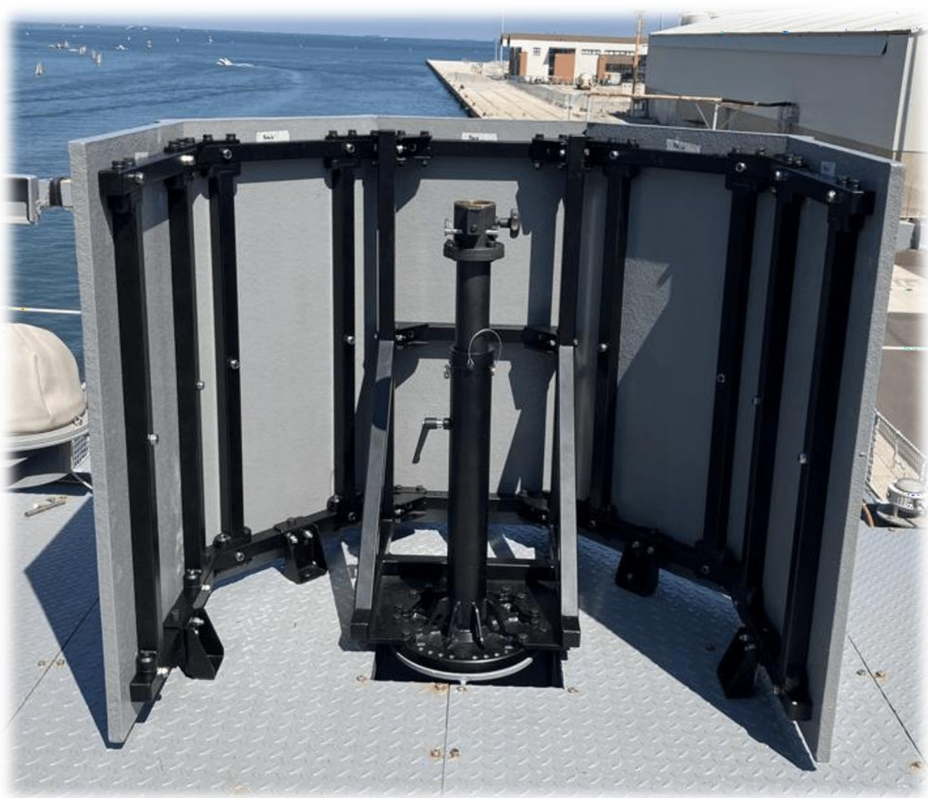
- LegionPolyethylene
- Ceramitech–Ceramic Armor
- LegionAramid

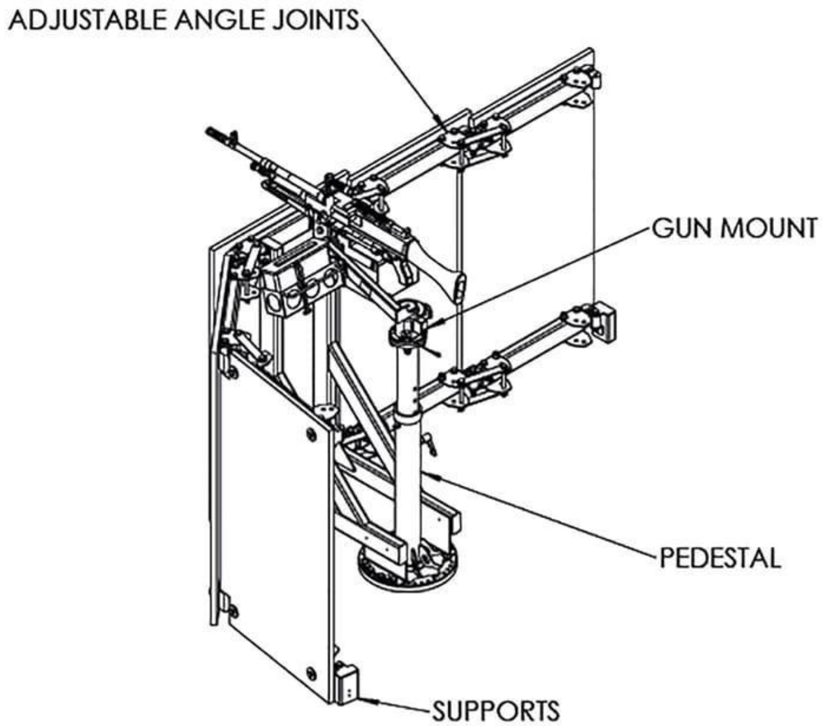
ASLGRPMarine Shield

TheASLGRPMarineShieldsystemisaretro-fitprotectionforvesselmountedweapons. Legion Polyethylene or Ceramitech panels provide a 3x or 5x panel configuration to protect the operator from 180 degrees of attack. The Marine Shield system can be fitted with a pedestal and gun-mount or be integrated with a vessel's existing pedestal. The shield framework can be manufactured from galvanized or stainless-steel dependent on the operator's requirement.

PrivateSectorVessels

Weareabletodesignandsupplybespokesolutionsforprotectingprivate superyachtsand tenders. From installation of panic rooms (citadels), to multiple room protection, we work with boatyardsundertakingrefitsofexistingvessels,and yachtdesigners.Ourteamcanundertakefull project management.





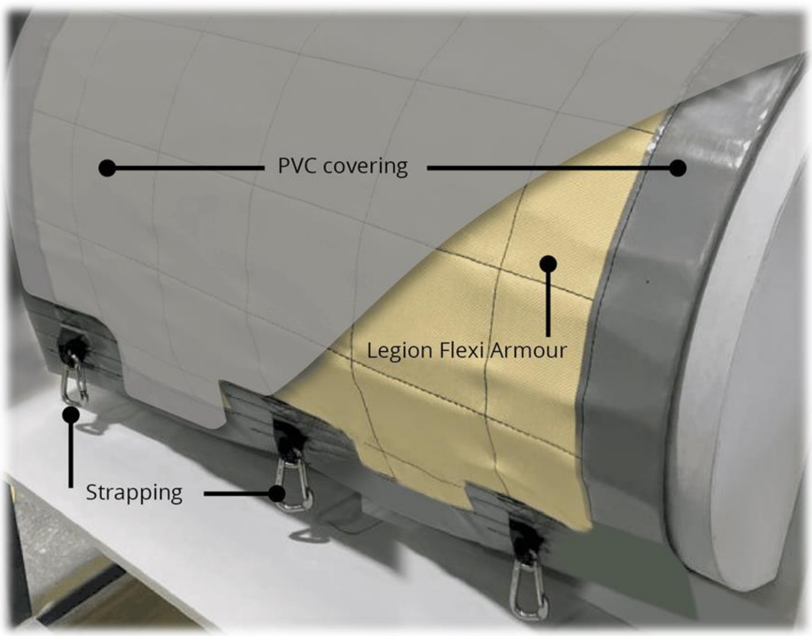
RIBS

We manufacture and supplypre-engineered, bespoke kits to provide RIBs and fast patrol vesselsprotectioninhighriskareas.Usinglightweightmaterials,weareabletoprotectthevessel without affecting top speeds and performance. Commonly protected areas include:

- Consoles
- Crew area
- Outboardcovers
- RIBtubes

Suggestedproductsfor RIBs:

- LegionPolyethylene
- LegionAramid
- LegionFlexi Armour


PVC covering
Legion Flexi Armour
Strapping

Conclusion

Thisinvestigationaimedtoexploretheroleandimpactofspecializedtextilematerialsused in automotive safety applications, focusing on ballistic nylon, polycarbonate polymers, Kevlar, andfiberglass.Thesematerialswereanalyzedfortheirproperties,suitabilityforvehicularsafety, and potential applications across various automotive components. Key findings include:

- **Ballistic Nylon:** Demonstrated high tear resistance and durability, attributed to its dense 2×2 basket weave structure and high-denier nylon threads, making it suitable for areas requiring enhanced abrasion resistance.
- **Polycarbonate Polymers:** Offered significant impact resistance, thermal stability, and optical clarity, positioning them as ideal materials for vehicle windows and other transparent components requiring both durability and visibility.
- **Kevlar:** Known for its high tensile strength and resistance to extreme conditions, Kevlar was identified as an effective reinforcement for vehicle doors, armor plating, and other areas needing high impact absorption.
- **Fiberglass:** Showed versatility in automotive use, with its composite structure providing both strength and flexibility, particularlysuitable forstructural components where weight savings and thermal stability are required.

Reference

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