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Concept of the defense material system for the security of Indonesian national armed personnel against threats

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Abstract

It is essential to have materials that can support armor systems for the application of body armor composed of anti-ballistic material from coated fibers in trials in order to defend military personnel with better ballistic performance who are lighter against growing threats and conflicts. to support defense-related ballistics. New materials used in personnel protection systems are the subject of this discussion. As ballistic shields, fiber composite materials are currently used due to their light weight and high flexibility. This essay also discusses a thorough analysis of mechanism performance and failure. This study's goal is to advance knowledge about composite material body armor that is covered with a soft spall liner material, which can be used as a model for lightweight, affordable, and safe designs for military troops in times of conflict.

Keywords: body armor, fiber materials, ballistic protection.

1. Introduction

One of the ways the development of the defense industry in the area of materials supports the Indonesian National Armed defense equipment's availability in preserving and maintaining the security of the territory of the Unitary State of the Republic of Indonesia. One of them is the development of bullet-resistant materials, also known as armor, which has been widely carried out through the development of new materials, composition integration, heat treatment, surface coating, and the manufacture of composites made of both metallic and non-metallic materials[1]. In order to increase defense mobility, particularly in the technology of the defense sector, namely in the material section, the government has developed a policy relating to updating and modernizing defense and security equipment (Alpahankam), known as the Minimum Essential Force. [2].

The protection of protective armor parts used to protect a person, vehicle, or device from penetration risks that may occur from devices used for explosive or ballistic events is one highly significant material development. Protective armor was typically comprised of metal, ceramic sheet, or a combination of these materials. These materials can be made better despite generally offering decent protection. More specifically, it would be great to offer armor that may be lighter than conventional armor [3].

Developing armor that can protect against various projectile threats, such as solid particles and molten metals, is desirable, for example composite fiber material. Furthermore, it is better to have defensive armor that is made of materials that are inexpensive and simple to build. Similar to soft body armor, stiff plates that shield vital organs from small-arm fire can be added to body armor. Body armor has historically had to function against both deformable (bullets) and non-deformable (shrapnel) threats in order to meet international military requirements. Usually, each end user develops their own performance requirements. It may incorporate widely accepted (public) standards at times, either with or without the need for extra testing [4].

General performance tests, such as those commonly referred to as the V_{50} test and the V_0 test, may be used to test soft body armor. In order to calculate the velocity (V) at which 50% (V_{50}) or 0% (V_0) of the projectile completely penetrates an object, it is necessary to repeatedly strike the target with the threat [5].

The standard polymer fiber materials that are used into the present armor protection systems for military vehicles against threats are the first thing we discuss in this review. The review is then divided into four sections, which each highlights a superior mechanical characteristic of polymer composites created for ballistic purposes. Epoxy-based composites have a great potential for application in military vehicle body armor in times of war to shield soldiers from threats as an alternative to aramid materials typically utilized in multi-layered armor systems (MAS) [6].

2. Research method

This paper is review article which explained about the behavior of the defense material concept in protecting Indonesian National Armed personnel is examined in this research using a qualitative approach of literature review. Based on research findings relating to the subjects and ideas that were acquired from earlier researchers and practitioners, the discussion or analysis is conducted. One method of research is conducting a literature review. Comparing literatures to other research methods, they each have their unique challenges. Because doing a study of an issue that has to be solved in relation to the theory to be utilized, the model to be used, or the method to be used calls for a high level of understanding from researchers. Finding and determining the literature that is pertinent to the topic is one of the stages in this literature review research. This activity calls for a high concentration on locating data sources, particularly secondary data in the form of journals, articles, and books; the more sources used, the better the results. Filter the sources that have been acquired for use in problem-solving by performing literature screening. At this point, the literature review's difficulty level is at its highest since it must be able to fill in any gaps in the current theories using sources, analyze the benefits and drawbacks of each source, and conclude based on the discussion's findings to provide a solution to the problem.

3. Results and discussion

3.1 Conditions structure protection from threats

Studying the development of military equipment is essential, especially in protecting soldiers from enemy threats while maintaining a high level of personnel mobility. This is the result of advances in weapons technology, particularly in the field of materials. Because the TNI must be free to move in the field, the performance of the necessary personal protective equipment must also be good. The Indonesian National Army needs to be protected from threats, so protection requirements are important.

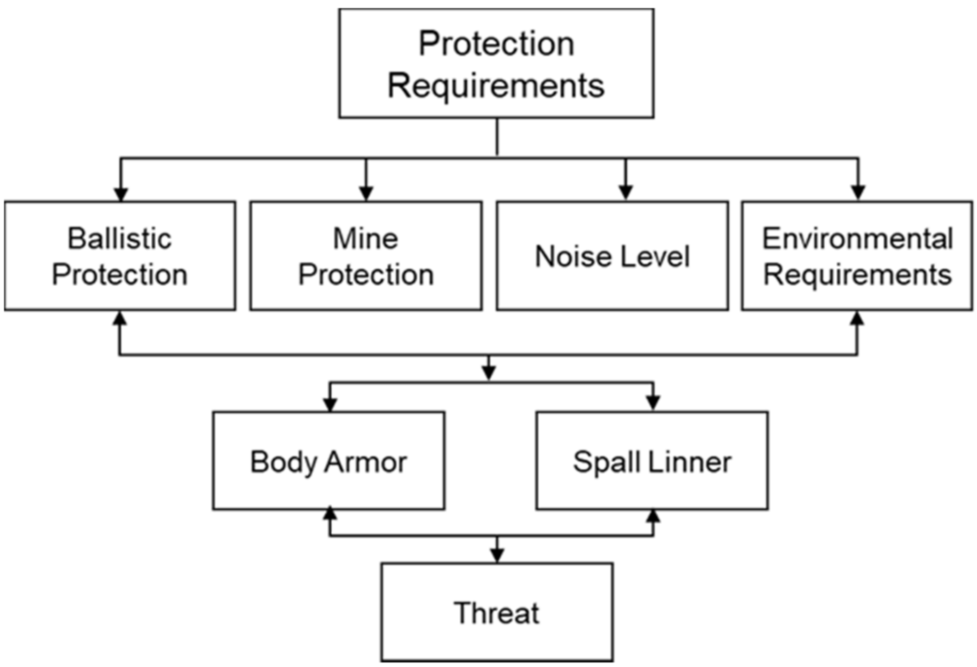

Figure 1. Concept of Threat Protection Requirements.

Figure 1 shows the key factors that must be taken into account for protecting military vehicles from threats are ballistic protection, mine protection, noise levels, and the environment. When there is a threat, these components are in the body armor and spall liner to protect military vehicles, especially porcelain. In military operations and peacekeeping, military vehicles are crucial. The type and level of armor protection required for many military vehicles depends on the objective. Combat vehicles need to be protected from projectiles, shrapnel, explosive bursts, missiles, and other hazards that could endanger the lives of military personnel [7].

3.2 Body armor made of ballistic panel composite

With the growth in threats and conflicts over the past few decades, there has been a lot of interest in the development of personal protection systems with improved ballistic performance and less weight. In this study, many nanomaterials, including carbon nanotubes and graphene with advanced structural and mechanical properties, as well as their strengthening potential of armor composites, are typically used as polymer fibers in the manufacture of body armor [8] examined using a variety of recent studies that are listed in the literature. Additionally, natural fibers are incorporated into multi-layered armor systems and ballistic testing that support their importance in the near future. The new materials that are used in specific and important body armor protection systems with the goal of creating the durable and lightweight body armor of the future are the main subject of this brief.

Table 1. Mechanical properties of high-performance polymeric fibers [9]

Fiber	Density, (r), (kg/m^3)	Modulus (E), (GPa)	Specific strength (MPa/(g/cm^3))	Strength (s), (GPa)	Strain to fracture (e), (%)	Specific modulus (MPa/(g/cm^3))	Sonic velocity, v_s, (m/s)	Specific energy absorption capacity (m^2 /s^2)
Nylon 6	1140	3	0,44	0,5	18–26	2,63	1622	57,017
S2 Glass	2500	86	1,8	4,5	1,8–5,4	34,4	5865	48,600
Cotton	1550	6–11	0,19–0,45	0,3–0,7	6–7	3,87–7,10	2663	15,806
Silkworm Silk (Bombyx mori cocoons)	1320	5	0,38	0,5	15	3,79	1946	28,409
Spider silk (Dragline of Nephila)	1320	22	0,98	1,3	40	16,67	4082	196,969
M5 Fiber (Goal)	1700	450	5,59	9,5	2,0-2,5	264,71	16,269	69,852
M5 Fiber (Conservation)	1700	300	5	8,5	2,5	176,47	13,284	62,500
Zylon HM	1560	270	3,72	5,8	2,5	173,08	13,155	46,474
Spectra 1000	970	120	2,65	2,57	3,5	123,71	11,122	46,365
Dyneema sk 76	970	116	3,71	3,6	3,8	119,59	10935	70,515
Kevlar 29 (1500 denier)	1440	74,4	2,01	2,9	3,38	51,67	7187	34,034
Kevlar 49 (1140 denier)	1440	120	2,11	3,04	2,3	83,33	9128	24,277
Kevlar 129 (840 denier)	1440	99,1	2,25	3,24	3,25	68,82	8295	36,562
Kevlar KM 2 (850 denier)	1440	73,7	2,32	3,34	3,8	51,18	7154	44,006
T–1000 (Toray)	1820	294	3,88	7,06	2,4	161,54	12,709	46,549
P–120	2190	827	1,02	2,24	0,2	377,63	19,432	1022
SWCNT-a	1400	1000	9,29	13	16	714,29	26,726	742,857
SWCNT-b	1400	1000	37,86	53	16	714,29	26,726	3,028,571

Table 1 displays the relationship of speed and energy absorption capacity in addition to the types of materials punched from the mechanical properties associated with their individual strengths (toughness) [8]. There is a lot of potential for armored applications in the new high-performance fibers based on polypyridobisimidazole that also have very high specific energy absorption capacity and sonic velocity. Table 1 illustrates the specific strength of the material plotted against the specific stiffness in Figure 2, while the sonic velocity plotted against energy absorption capability (toughness) is shown in Figure 2. Due to its extremely low specific energy absorption capacity, ultra-high modulus carbon fiber, which has the highest strain wave velocity when compared to other fibers, is frequently employed in ballistic applications.

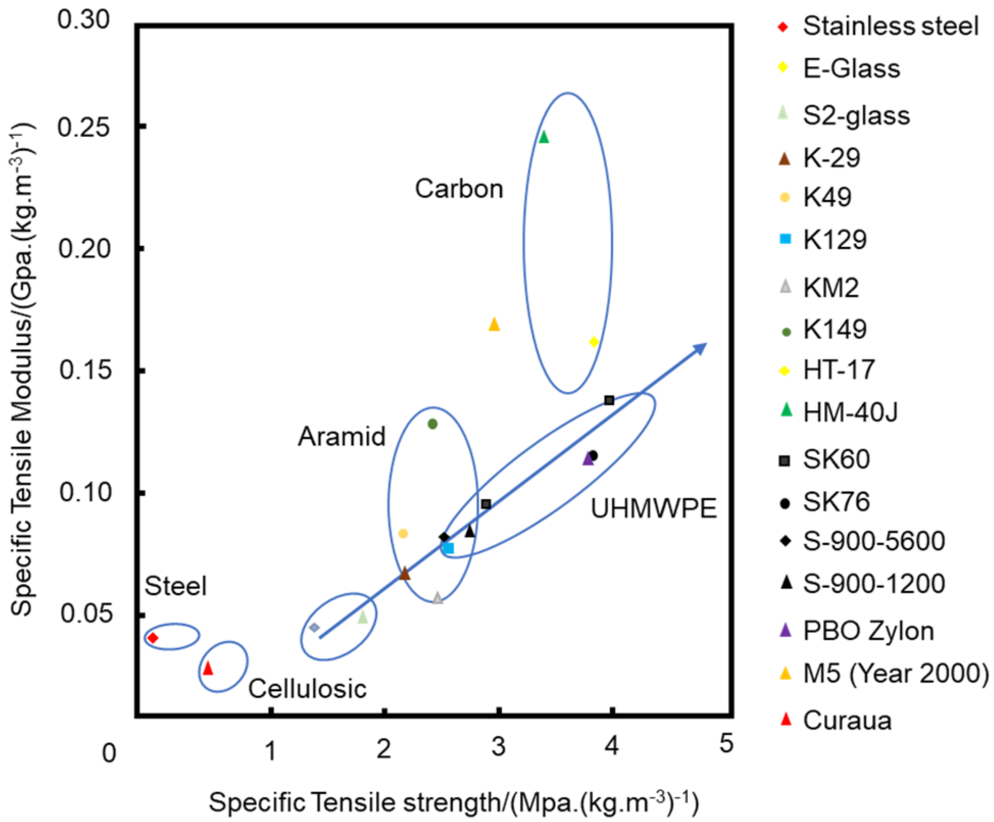

Figure 2. Specific tensile strength and modulus of high performance fibers [10].

Figure 2 illustrates the relationship between high-performance fibers' specific tensile strength and specific tensile modulus when the latter is determined from bending tests and employed in structural composite applications.

3.3 Spall liner for soft body armor

Armored equipment mounted on the hull of a ground vehicle protects the soldier inside the vehicle to increase survivability. There are additional components that exist inside and outside the ground vehicle but do not add to its structural integrity. The composite used is referred to as a spall liner.

The term "spall liner" refers to soft materials that are installed in the crew compartment of vehicles and line the interior surfaces of tanks, combat vehicles, and personnel carriers as a form of interior protection. These materials are typically made of laminated aramid fiber, glass fiber, or high density polyethylene (HDPE). The purpose of the spall liner is to shield the defensive personnel from being struck by fragments (spall) created during combat. If the armor system is "overmatched," which is the phrase used when the incoming bullet has more penetrating strength than the armor's stopping capability, spall liners can be added as additional security [6]. Figure 2 an d show in examples of a spall liner that helped save individuals who were outclassed.

Table 2. Physical properties of glass fiber, aramid fiber, and ultrahigh-molecular-weight polyethylene (UHMWPE) fiber [7][10]

Fiber	Density (g/cm^3)	Young's Modulus (GPa)	Tensile strength (Mpa)
UHMWPE fiber	0,97	62-132	2200-3900
Aramid	1.44	70-112	1880-2860
S-Glass	2.49	89	4750
E-Glass	2.55	90	2000

Characteristics of the Spall liner material, a molecular structure and high-performance chemical and polymer surfaces that is used to make body armor protection vehicles. Table 2 displayed to one of the materials that doesn't contain chemical components that are susceptible to attack from aggressive agents is UHMWPE, which has a low surface energy and is very resistant to water, humidity, most chemicals, UV radiation, and microorganisms. This allows it to bond with other polymers and adhere to surfaces for coating or more challenging painting. Performance of composite varies with threat. As a result, UHMWPE is a material that is very effective at reducing the threat posed by deformable bullets. For example, UHMWPE can be as little as half to one third the weight of aramid and glass composites and still perform comparably well in stopping typical deformations that an assault rifle or sniper rifle threatens to do on its own. UHMWPE often uses 20–50% less material for the same performance in terms of fragment protection. It is difficult to predict how different composite materials, such metal or ceramic, will operate in a system composed of several components [6].

3.4 Vehicle spall liners

Thermoset resins and thermoplastic resins are two types of polymer matrices that are frequently utilized in the military. Phenolic, epoxy, vinylester, and polyester are the four most often used thermoset resins in ballistic composites. Phenolic resins are frequently selected because they work well with glass and aramid fibers and are fire retardant, liquid and chemical resistant, stiff, and have good ballistic efficiency. Because of its excellent toughness, high mechanical and thermal qualities, superior water and thermal resistance, low shrinkage rate, and ease of fabrication, epoxy resin was chosen. Vinylesters combine outstanding mechanical characteristics with simplicity in fabrication [11].

This para-aramid fiber is five times stronger than steel and performs better in ballistic tests than nylon. Because they have benefits in several aspects, ultra high molecular weight polyethylene (UHMWPE) fibers have started to be exploited for ballistic applications recently [12].

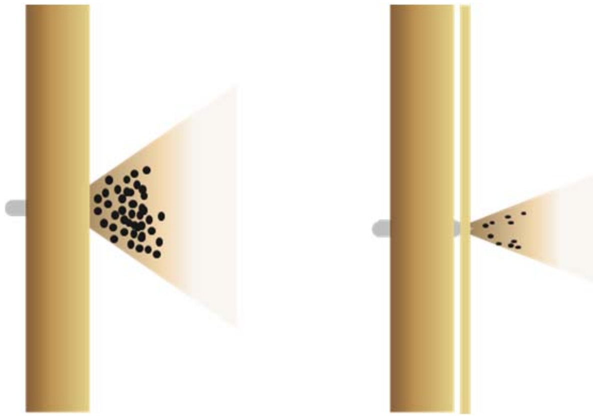

Figure 2. A spall liner is used on a light armored vehicle [7].

Below is a hypothetical armored personnel carrier with a life-saving spall liner in an overmatch. As can be seen, the spall liner significantly reduced the spread of fragmentation while protecting lives.

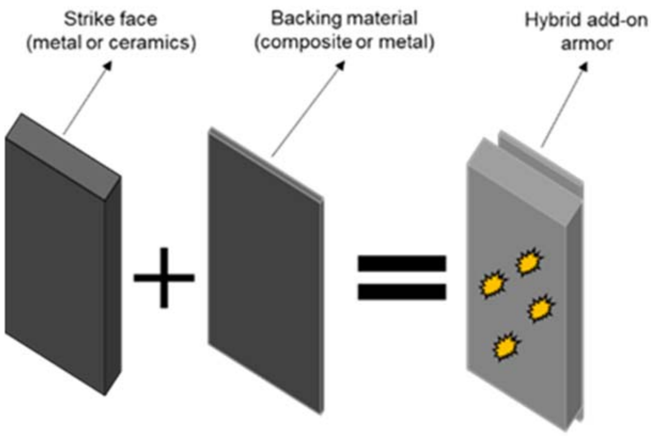

Figure 3. Armor design [7].

Vehicle makers and armored integrators have created a variety of inventive connection techniques that enable soldiers to quickly install these auxiliary systems in the field with extremely basic and limited gear [6]. Hardness ratings and impact load resistance are related to resistance to ballistic loads. Projectile penetration will be more difficult the harder the material is. However, because to the projectile's high velocity of impact, resistance to shock loads is also necessary, necessitating considerable toughness in the material.

A tank is an example of a ground vehicle that needs to have the type of armor used depending on the mission and threat environment. When operating in challenging terrain, special operations must be agile. Protection is thus needed from surprise attacks as well as while confronting small arms fire.

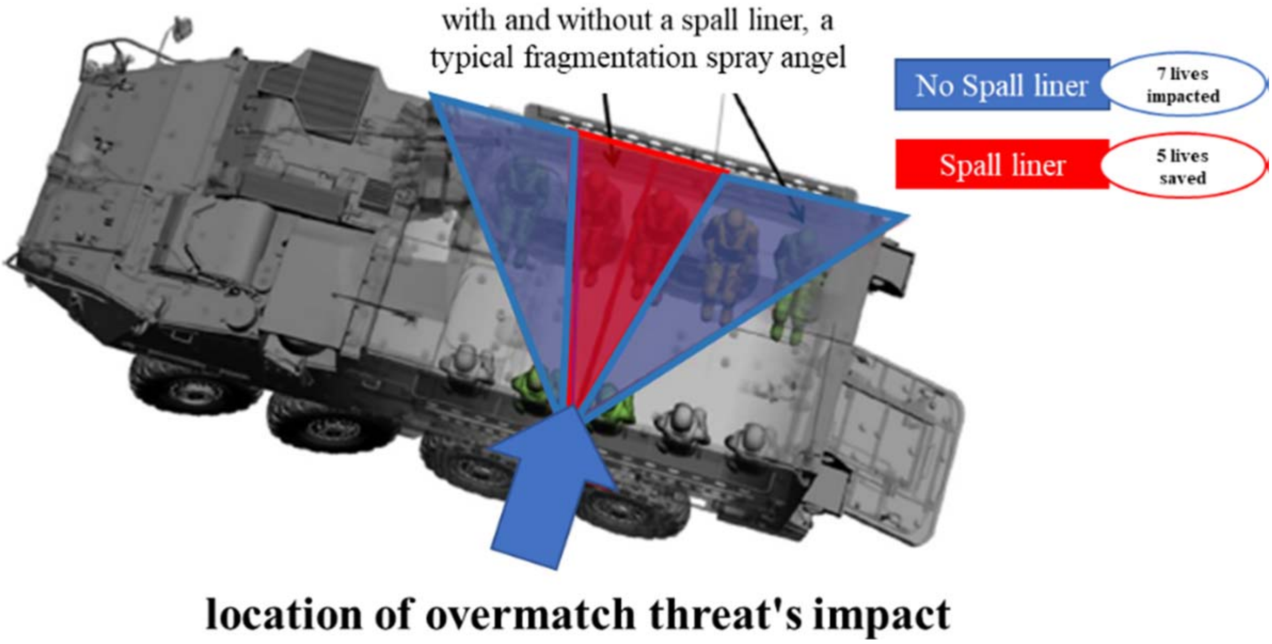

Figure 4. Spall liner saves lives in overmatch in hypothetical armor personnel carrier [7].

From the illustration Figure 4 show is crew safety from large-caliber armor-piercing (AP) rounds, landmines, and rocket-propelled grenades. Special operations vehicles, for example, cannot be constructed for this level of protection and still be agile. Material selection is intended to handle the weight required to give protection from such threats. The weight or areal density of the spall liner and the material used in it all affect how far the cone angle can be reduced.

As shown in Table 2. composite materials with higher performance have a lower cone spall angle while being lighter in weight. Utilization of the spall liner has begun to develop into a part of the overall armor system, which will also contain the hull (basic armor), spall liner within the vehicle, and additional armor protection linked to the outside of the vehicle [13]. The objective of additional armor, which is frequently high-hardness steel or ceramic, is to break or bend incoming projectiles, while the metal hull and composite spall coating are designed to catch shards [7].

Table 3 displays the STANAG 4569 threat level. At the bare minimum range they are anticipated to be encountered, the speeds shown in the table are the anticipated ammunition velocity. In terms of the capacity to penetrate armor, the lower threat levels are the least deadly, and this tendency grows as the threat level rises numerically. Occasionally, more than one threat is defined to some extent. For instance, the penetration capabilities of two category 3 threats are comparable. Both have 7.62 mm diameter high-penetrating tungsten cores, however one (B32) is significantly heavier (10.0 g vs. 8.4 g) and has a slightly slower velocity (854 m/s vs. 930 m/s) [5].

Testing the area density panels above and below the intended V_{50} results in the answer for threat level 4 being near to the ideal solution. The answer is then extrapolated using the test findings. The most current data, level 5 testing, were conducted on panels with area densities as high as 200 kg/m^2, which did not provide the necessary protection. As a result, extrapolation from the tested panel configurations led to the panel constructions proposed in the table for protection level 5. The suggested protection was extrapolated from the areal densities above and below it at all other levels .

Table 3. Threat Solutions and Composite Protection Levels for STANAG 4569 [5]

Threat	Ammunition	V_0 (m/s)	Threat type	Panel construction	V_{50} (m/s)	Area density required (kg/m^2)
5	25 x 137 mm APDS-T, PMB 073	1258	Auto Cannon, APDS Ammunition	88 mm PMB 073 composite, 25 mm ceramic surface	1258	276
4	14,5 x 114 mm API/B32	911	Heavy Machine Guns, AP Ammunition	16,5 mm, facing ceramic 15 mm	911	90,5
3	7,62 x 54R mm B32 API	854	Assault Rifles and Snipers, AP WC Core	25 mm API composite, ceramic facing	854	67,5
2	API BZ	695	Assault Rifle	8 mm composite, 8 mm ceramic facing	917	46,6
1	7,62 x 51 mm NATO ball	833	Assault Rifles/ Ball Round	Surfaceless composite panels	833	48,2
1	5,56 x 45 mm M193	937	Assault Rifles/ Ball Round	Surfaceless composite panels	937	38,4

When a threat from high-hardness armor with a bullet-defeating system is present, Then add the right coating material. Through tests and simulation, it was established that the mechanism of the bullet in armor testing includes (a) asymmetrical forces that cause the projectile to deviate from the incidence trajectory, (b) core fracture, and (c) erosion of the nose of the core. With this technique, good agreement was demonstrated between the simulated and experimental base armor penetration depths and the post-ballistic deformation pattern of perforated plates [14]. Based on the threat level given in the table, it is clear that military vehicles' body armor needs to be strengthened in addition to being constructed from materials that must be appropriate for the type of threat and the need to produce materials in line with threats now in existence.

4. Conclusions

The desire for light, flexible, and robust bodies that can give better ballistic protection is growing as technology, particularly in the area of materials, progresses, especially in light of the increasingly deadly dangers that troops will be subjected to. Polymer fibers and composites have been used to create a variety of materials that are stiff, strong, and lightweight. Without a doubt, the development of fiber as ballistic protection holds significant promise for assisting and protecting Indonesian National Armed soldiers in the future.

The most recent composite material to be developed for vehicle armor body materials is sandwich structure polymer composite material. Along with the significance of Soft Body Armor Spall Liner Composites, which are made of a variety of materials including UHMW PE, Aramid, S-Glass and E-Glass to composite material has good test results and can be employed as an armor body structure material to shield troops from dangers.

Declaration of competing interest

The authors declare that none of the topics discussed in this paper are the subject of any known financial or non-financial competing interests held by the authors.

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