
Effectiveness of Kevlar-Polyethylene Composite Material in Increasing Ballistic Protective Resistance against High Caliber Weapons

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Abstract

Kevlar-Polyethylene (UHMWPE) composite materials have become a focus in the defense industry to improve the durability of ballistic armor, especially against high-caliber weapons. Kevlar is known for its high tensile strength and resistance to penetration and heat, while UHMWPE offers elasticity and effective energy absorption. The combination of these two materials creates a composite that is not only lightweight, but also able to withstand projectile penetration better through energy dispersion and absorption mechanisms. This study aims to evaluate the effectiveness of Kevlar-Polyethylene composites in providing ballistic protection for high-caliber weapons. The results show that the use of this composite significantly improves ballistic protection performance compared to conventional materials, due to its synergistic properties. In addition, this composite shows good resistance to extreme environments, thereby increasing service life and efficiency in defense applications.

Keywords: Kevlar, UHMWPE, Composite, Ballistic, Protective.

INTRODUCTION

Indonesia's current defense situation faces various challenges. Challenges can come from other countries or non-state organizations. Current developments have led to increasingly sophisticated technology, leading to increasingly modern weaponry. The development of modern technology, particularly in the field of weapons, has motivated the Indonesian industry to develop better and more superior protection systems. This protection refers to protection designed and developed for use by military personnel and security forces. In any dangerous situation or conflict involving the use of weapons, there are inherent risks and impacts associated with the weapons used. The use of weapons or defense equipment in a conflict inevitably leads to casualties. Being shot, hit by projectile fragments, hit by grenades, and other injuries are among the causes of casualties in armed conflict situations. (Ding et al., 2022).

From the explanation above, a material is needed that can be used to make ballistic shields to face these threats. The required material is expected to be lighter, stronger, and have high impact absorption properties that will affect the resistance to high-speed projectiles. The material commonly used for ballistic shields is steel, but steel is heavy and this can hinder the mobility of personnel. Ballistic shields are devices designed with specific materials to protect the human body, structures, and vehicles from projectiles released by firearms or the impact of an explosion. Ballistic shields have several types that can be seen from their intended use. To protect the body, can use a bulletproof jacket, for the head can use a ballistic helmet. For vehicles can use vehicle armor, and in buildings can use structural protection. (Ursache et al., 2023).

Kevlar-Polyethylene is a type of combined material or composite designed or manufactured to increase the durability of ballistic protection. Kevlar is a synthetic fiber that has high strength and high resistance to pressure and impact. Kevlar is also an aromatic polymer that has very high tensile strength, making it quite efficient in resisting the impact force from projectiles. Kevlar also has viscoelastic properties that enable this material to absorb kinetic energy and distribute it throughout the composite structure. Polyethylene is a lightweight thermoplastic material that has high energy absorption properties. The Kevlar-Polyethylene mixture provides maximum protection against high-speed projectiles without increasing the weight of the product. This composite material is made of Kevlar fibers positioned in layers and combined with high-pressure polyethylene sheets. The

placement of these layers allows the composite material to distribute impact energy from impacts more evenly and effectively. This composite material also has a special resin coating that can increase durability when faced with extreme temperatures and other environmental factors.(Ding et al., 2022).

This Kevlar-polyethylene composite has the advantage of being lightweight compared to steel or other materials. This lightweight material allows for maximum and unimpeded personnel mobility. This composite also provides high resistance to projectile penetration and is able to absorb impact energy more efficiently and effectively. This impact energy absorption ability helps reduce the risk of injury from explosions or gunfire.(Findik, 2023)

This Kevlar-polyethylene composite material also has drawbacks, namely its limited high-temperature resistance and continuous exposure to ultraviolet light will cause the Kevlar-polyethylene structure to weaken. To overcome this, namely by adding a protective layer or using new fabrication technology to increase the material's resistance to external environmental factors. With new and continuous innovation, this material can continue to be developed to become a better ballistic protection solution in the future.(Liang & Zhao, 2023).

RESEARCH METHODS

This research was conducted using a literature review model, utilizing several journals or previously conducted research. This study was conducted to determine the effectiveness of Kevlar-Polyethylene composite material in increasing durability as ballistic protection against high-caliber weapons. This study has several main test parameters, namely the density and energy capacity of a material, energy absorption capacity, and temperature resistance. This study was conducted using previous research journals as references. The journals used were research journals conducted within the last 10 years before this literature review was conducted.(Bandaru et al., 2025).

The research method for this literature review uses a systematic and structured approach to detail relevant findings from various sources. This method was also chosen because it can evaluate the effectiveness of Kevlar-polyethylene material in increasing the durability of ballistic protection against high-caliber weapons.(Beny Bandanadjaja, 2009). This research process consists of the following steps:

Source collection

Source collection was conducted by searching for scientific sources, such as books and journals, published over the past ten years. The journals and books collected included both domestic and international journals, as well as books from both domestic and international sources. These books and journals discuss the techniques, properties, and testing of Kevlar and UHMWPE materials in the areas of ballistic resistance and durability in composite material testing.

Inclusion and exclusion criteria

The criteria used were studies that tested Kevlar, UHMWPE, or a combination of the two as ballistic protective materials. Studies focused on and relevant to these materials were also used as references in the material review in this journal.

Data analysis and synthesis

Analyze the results of various existing studies on ballistic resistance, the mechanisms and methods of energy absorption, and compare strength and performance with other materials. Compare data from various experiments and bullet deformation. Compile the study results into a narrative that illustrates the effectiveness of Kevlar-polyethylene as a good material for use as ballistic protection.

Critical evaluation

Conducting assessments regarding the validity and reliability of the research results reviewed, and identifying existing research gaps and potential for further study and research.

RESULTS AND DISCUSSION

Kevlar is an aramid fiber material with high strength and stiffness. Composed of long polymers with very strong hydrogen bonds between molecules, Kevlar is impact-resistant. This material has high tensile strength, is lightweight, heat-resistant, and resistant to chemicals. (Cao et al., 2021) Kevlar is designed and manufactured to withstand ballistics, tearing, and wear. Another advantage of Kevlar is its fire resistance. This ability is the basis for Kevlar's use in body armor, helmets, and vehicle armor. Its resistance to tearing and wear increases the material's lifespan.

Ultra High Molecular Weight Polyethylene Polyethylene is a material with a high molecular weight and very high mechanical properties. This material has energy absorption and is resistant to abrasion. The reason this material can withstand impact is because it has a long polymer chain structure. UHMWPE has high strength properties, is lighter than Kevlar, has a low coefficient of friction, is wear-resistant, and is chemically resistant. UHMWPE material also has the advantage of being ballistic and abrasion resistant. Other advantages or strengths of UHMWPE material are high energy absorption, which can absorb energy from impacts without permanent deformation, and is very light, which is lighter than Kevlar. (Kumar et al., 2021).

By knowing the properties of UHMWPE and Kevlar, a combination of Kevlar and UHMWPE is carried out in a composite material. This combination of materials creates a more optimal protection technology because it combines the strengths of the two materials. Kevlar makes the composite have high strength and heat resistance, and UHMWPE adds elasticity and energy absorption capabilities. The advantage of this combination is increased ballistic efficiency obtained from UHMWPE as a projectile absorber and Kevlar which can stop projectiles because of its fibers. Another advantage of this combination is that the product will be lighter and more flexible resulting from the combination of these two materials without sacrificing its level of protection. Kevlar in this mixture also functions as a reinforcement, while polyethylene functions as a matrix that binds the Kevlar fibers, thereby increasing the performance of the composite under pressure or impact.

The composite of these two materials is made using common fabrication techniques, namely lamination and layered fiber creation. The lamination is made by sequentially stacking layers of Kevlar and polyethylene. Each layer is added with a resin or polymer matrix to increase the strength between the Kevlar and polyethylene. In addition to increasing strength, the resin also makes this composite have impact resistance. This technique allows control of the thickness and orientation of the fibers, which can affect the overall material. The strength resulting from this material blend adds added value, namely having a light weight, high tensile strength, and the ability to increase ballistic resistance, namely resisting bullet penetration and reducing material deformation when exposed to high-speed impacts.

This composite works through the energy absorption mechanism of Kevlar. The aramid fibers in Kevlar, which have high tensile strength, work by absorbing and distributing the kinetic energy from the bullet over a wider area. In this mechanism, Kevlar deforms and dissipates the energy through the mechanism of fiber fracture or fiber breakage and delamination or separation of the fiber layers. Delamination can reduce the speed of the bullet and reduce penetration into the protective material, and can distribute energy more effectively. In UHMWPE material, this material can stretch without breaking its bonds. And distributes the impact force more evenly across the surface. UHMWPE also has the ability to absorb energy and reduce permanent deformation, which can protect the body from damage caused by bullet penetration. Kevlar in this composite provides heat resistance, while UHMWPE provides elastic and energy absorption features. This combination creates efficient and lightweight protection for the user.

Kevlar is an aramid fiber material with high strength and stiffness. Composed of long polymers with very strong hydrogen bonds between molecules, this makes Kevlar impact resistant. This material has high tensile strength, light weight, heat resistance, and chemical resistance. Kevlar material is designed and designed to be ballistic resistant and resistant to tearing and wear. Another advantage of

Kevlar is that it can be a fire-resistant material. This ability is the basis for Kevlar material being used as a component of body armor, helmets, and vehicle armor. Resistance to tearing and wear increases the service life of this material.

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The following is a comparison table showing the tensile strength and density comparison between Kevlar-polyethylene composites compared to steel, iron, and ceramics.(Roberts et al., 2017):

Table 1. Comparison of Density and Energy Capacity Data

Material	Tensile Strength (MPa)	Density (g/m ³)	Energy Absorption Capacity	Resistance to High Caliber Bullets
Kevlar-polyethylene composite	3000-3500	1.4-1.5	Very high	Effective, lightweight, and high energy absorption
Steel	400-900	7.8	Low	Very durable, but heavy
Iron	250-400	7.8	Low	Less efficient than steel
Ceramics	1000-1500	3.5-3.9	Tall	Very durable, but brittle and prone to breaking

Kevlar-polyethylene composites have significantly higher tensile strength than the other three materials: iron, steel, and ceramic. The comparison in the table also includes density and resistance to high-caliber bullets. This is due to Kevlar's ability to distribute energy and UHMWPE's ability to absorb impact from projectiles, thus preventing significant deformation. Steel and iron are bulletproof, but they are also heavier. This can hinder their use and reduce flexibility and mobility for the wearer. Ceramic materials offer bulletproof resistance due to their hard properties. This is evidenced by the table, which shows that ceramics have a tensile strength of up to 1000-1500 MPa. However, in terms of elasticity, ceramics are more fragile and easily broken, making them more suitable for additional protection on objects not attached to the body.

The density comparison of the materials in the table can also indicate and determine the effectiveness of ballistic protection. The table shows that the Kevlar polyethylene composite has a much lower density of 1.4-1.5 g/cm³ compared to iron and steel. For ceramics, the density is 3.5-3.9 g/cm³. The Kevlar-polyethylene composite has a low density that can provide advantages in reducing the load for the user without reducing its protective ability. UHMWPE plays an important role in increasing the effectiveness of Kevlar-polyethylene as a ballistic protector. This material is able to withstand high friction and impact, and is able to absorb energy from bullets with a mechanism that will spread energy or force throughout the composite area.

The following is a table of material resistance tests in absorbing energy from projectiles with material thickness as an indicator:

Table 2. Comparison of Energy Absorption Capacity.

Material	Material Thickness (mm)	Bullet Diameter (mm)	Strength (MPa)	Energy Absorption Capacity (J)
Kevlar-polyethylene	10	7.62	3000-3500	500-800
Steel	15	7.62	400-900	300-450
Iron	20	7.62	250-400	250-350
Ceramics	12	7.62	1000-1500	600-900

In the table above, it can be seen that Kevlar-polyethylene at a thickness of 10 mm has a high absorption capacity of around 500-800 J. When compared to steel and iron which have fiber capabilities below 450, of course Kevlar-polyethylene is superior. When compared to ceramics, the maximum energy absorption capacity of ceramics is 900. In terms of energy absorption capacity, the value of Kevlar-polyethylene is still below the energy absorption capacity of ceramics. When viewed in terms of efficiency, Kevlar-polyethylene is more efficient when compared to ceramics. This can be seen from the thickness of the Kevlar-polyethylene material and the thickness of the ceramic. Kevlar-polyethylene has a thickness of 10 mm with an energy absorption capacity of 500-800 J, while

ceramics with a thickness of 12 mm have an energy absorption capacity of 600-900 J. From this it can be seen that Kevlar-polyethylene has a higher efficiency compared to this material. The capabilities of Kevlar-polyethylene are due to the combination of the strong and elastic Kevlar fiber structure with UHMWPE which allows for the absorption and distribution of projectile energy evenly throughout the material. Each material has a different mechanism for determining the amount of energy absorption. Energy absorption in Kevlar-polyethylene is absorbed through deformed Kevlar fibers that distribute the resulting force from the impact and is further reinforced with a layer of UHMWPE that can slow projectile penetration. For steel and iron, why is it less efficient in absorbing energy, it is due to the nature of steel and iron which is less elastic. The harder nature of iron and steel causes plastic deformation that makes more energy transmitted than absorbed. In ceramics, the mechanism of energy absorption is through the process of fragmentation. Where ceramics will absorb most of the projectile energy but the ceramic will lose its protective structure in one impact and that is what causes the ceramic to break or shatter. From the table, it can be seen that the test was carried out by firing a 7.62 mm diameter projectile at each surface of the material. Energy analysis using pressure sensors and impact testing were also conducted to determine how much energy each material absorbs before it fails. This testing also reveals how efficiently a material absorbs energy when penetrated by a ballistic weapon. Material efficiency is crucial because it affects the material's weight, flexibility, and mobility once formed. The more efficient a material is when used as a product, the more useful it will be and the easier it will be to use.

An experimental study of this composite mixture was conducted to determine and test the durability of the Kevlar-polyethylene composite material when hit by bullets from high-caliber weapons. This test also allows for an evaluation of the material's ability to withstand and distribute the energy from the bullet to determine its maximum and effective capabilities for the user. Ballistic tests were conducted to determine how deep the bullet can penetrate the material, the level of deformation that occurs in the composite layer, and how well the material can withstand and absorb energy from the bullet or projectile. Kevlar-polyethylene also has the advantage of being lighter in weight. With its light weight, this material can be used as an object attached to the body. The lightness of this Kevlar-polyethylene material also makes an object made from this material have high flexibility and a high level of mobility. This makes it easier for the user to carry and wear it without any significant obstacles.

The following is a table of material trial tests when exposed to high temperatures:

Table 3. Comparison of Temperature Resistance Capability.

Material	Material Thickness (mm)	Test Temperature (oC)	Detected Strength (MPa)	Temperature Resistance (oC)
Kevlar-polyethylene	10	200	1500-2000	Up to 300
Steel	15	800	400-700	Up to 900
Iron	20	700	250-500	Up to 800
Ceramics	12	1200	1000-1300	Up to 1500

From the table, Kevlar-polyethylene has a limited heat resistance, which is a maximum of 300oC. This shows that although it has strong resistance in terms of tensile strength and can withstand bullet penetration, Kevlar-polyethylene still cannot be exposed to high temperatures exceeding 300 oC and if this happens, it can damage the Kevlar bond of the material. Iron has a resistance of 900 oC at a thickness of 15 mm. This is certainly good in terms of heat resistance but is very lacking in terms of the total weight that will be produced later when it is finished. If iron is used as a ballistic protection material, especially for use and attached to the body, the product will be very heavy later because the ratio of millimeter thickness is twice that of Kevlar-polyethylene. For ceramics, it is recorded that it can withstand temperatures up to 1500 oC, but this material cannot be fully used because it has low elasticity. So when used, it is susceptible to breaking and has short durability.

This composite material faces challenges in terms of performance degradation when exposed to extreme temperatures, high humidity, and prolonged exposure to UV radiation. The polymer bonds in UHMWPE can weaken when exposed to high temperatures, and Kevlar has the ability to absorb water, weakening its bond strength. Exposure to UV radiation can cause rapid degradation, damaging the structure and surface molecules, reducing ballistic resistance, and ultimately shortening the material's lifespan. Temperature resistance testing for each material uses a thermal test method with gradual heating. This gradual heating uses a furnace or heater at a specific temperature. In addition, the thermal test also uses Differential Scanning Calorimetry (DSC) to determine the melting point and degradation of Kevlar-polyethylene materials. Several studies have shown that degradation of Kevlar and UHMWPE can be accelerated when exposed to harsh environments. Kevlar will experience a decrease in tensile strength if exposed to humidity for a long time, while UHMWPE can become brittle after exposure to UV light. The durability of Kevlar-polyethylene is also influenced by environmental factors and the effectiveness of the material. Environmental factors such as prolonged or continuous exposure to UV rays can reduce its durability or cause degradation. Preventing this material degradation is crucial to extend the material's lifespan and increase the efficiency and effectiveness of ballistic protection. To maintain the material's durability and strength, and prevent material damage, proper maintenance is required. Storing the material in a dry place, avoiding exposure to UV rays, and reducing exposure to high temperatures can prevent damage. Proper maintenance of this material also increases the lifespan and useful life of items made from this material.

Kevlar-polyethylene composite materials are more expensive than other materials. This high cost is due to the complex fabrication techniques and processes used to produce the material, along with the high cost of raw materials. However, this high cost is offset by significant weight reduction, which contributes to increased mobility and user comfort, as well as operational efficiency in military applications. In large-scale production for military needs, this material boasts high efficiency. Despite its high cost, the material's capabilities and advantages can be offset by the costs. The material's light weight allows for savings in logistics and transportation. This material can also be molded into any protective clothing due to its high flexibility, which allows for high mobility. Bulletproof vests, vehicle panels, bulletproof helmets, and other items can be formed from this material, which can be used for protection against projectiles or ballistic attacks. Although the initial cost of manufacturing this material is very high, in the long term, it is durable and offers strong durability. The use of this material is also tailored to military needs, especially for direct contact. This material offers other capabilities and advantages, including corrosion resistance and resistance to degradation when used with proper care. Its use and production are still considered commensurate with the costs involved.

The combination of Kevlar and polyethylene (UHMWPE) creates a superior composite material with high tensile strength. This is due to the combination of Kevlar's tensile strength and polyethylene's elasticity and energy absorption capabilities. The primary protection of this material is Kevlar, which is able to withstand bullet penetration, while polyethylene helps disperse impact energy, reducing the risk of deformation and preventing further damage when resisting bullets from high-caliber weapons. This composite material has the advantage of being very effective for small to medium caliber bullets. This material may fail for high-caliber weapons or special projectiles that are beyond the material's resistance capabilities. This material still requires further evaluation and study to maximize the durability and efficiency of its features. To improve the performance of this composite, research is needed that focuses more on new innovations or additions to this material. Additions can include the addition of a ceramic layer or the development of a hybrid structure that is more efficient in absorbing and dissipating impacts in all directions, and ensuring ballistic protection remains effective in various conflict conditions.

An invention requires further innovation to develop further. Innovation in the field of ballistic protection can continue to develop, coupled with technological advances that also continue to advance and can collaborate to create better materials for use as ballistic protection. For example, innovation can be done by adding a ceramic seat or ceramic layer to a Kevlar-polyethylene composite. The hard

ceramic layer can disperse the projectile energy and become a layer or barrier before the projectile enters the Kevlar-polyethylene layer. Several new materials are also being explored, namely advanced polymet fibers, and nano-composites are being studied regarding their durability in reducing the total weight of ballistic protection. This is done to find even lighter materials for use as ballistic protection and can be applied in the military world, especially in direct conflict. Existing and modern composite technologies such as hybrid technology that combines materials with different mechanical properties such as ceramics, Kevlar, UHMWPE to create more efficient ballistic protection. This design is also designed to maximize the flexibility of Kevlar and ceramics that can withstand and protect optimally from various threats. Several recent studies on materials have focused on the integration of advanced materials such as carbon fiber, graphene, and elastomeric coatings to enhance protective performance. These materials also help distribute impact pressure evenly, utilizing the advantages of each.

CONCLUSION

Kevlar-polyethylene composites are generally recommended for ballistic protection due to the strength of Kevlar fibers and the bullet-proof properties of UHMWPE. This material is effective in resisting small- to medium-caliber ballistic attacks. However, this material also has limitations when exposed to high temperatures, UV rays, and extreme weather. Continuous innovation and research are needed to maximize and discover the advantages of this material, which can later be utilized in the military, especially in direct conflict, and provide better protection.

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