T.R.
VAN YUZUNCU YIL UNIVERSITY
INSTITUTE OF NATURAL AND APPLED SCIENCES
MECHANICAL ENGINEERING DEPARTMENT

INVESTIGATION OF BALLISTIC PERFORMANCES OF NEW GENERATION UHDPE MATERIALS

M.Sc. THESIS

PREPARED BY: Zuhair Omar Ahmed
SUPERVISOR: Asst. Prof. Dr. Halil Ibrahim YAVUZ

VAN-2018

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ACCEPTANCE and APPROVAL PAGE

This thesis entitled "**INVESTİGATİON OF BALLİSTİC PERFORMANCES OF NEW GENERATİON UHDPE MATERİALS**" presented by Zuhair Omar AHMED under supervision of Assist. Prof. Dr. Halil Ibrahim YAVUZ in the department of Mechanical Engineering has been accepted as a M.Sc. thesis according to Legislations of Graduate Higher Education on 14/09/2018 with unanimity / majority of votes members of jury.

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THESIS STATEMENT

All information existing in this thesis obtained according to the proper comportments and academic rule structure. Not all statement and information belongs to me. In this work prepared in agreement with the rules of these cited to the source of information.

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Zuhair Omar Ahmed

ABSTRACT

INVESTIGATION OF BALLISTIC PERFORMANCES OF NEW GENERATION UHDPE MATERIALS

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M. Sc. Thesis, Department of Mechanical Engineering
Supervisor: Assist. Prof. Dr. Halil Ibrahim YAVUZ
September 2018, 81 Page

Composite material is composed of several materials to obtain greater durability and better impact resistance, taking into account tow important factors, lightness and thickness.So that, the complex response of composite materials coupled with high costs and limited amount of data from ballistic testing has led to modeling and simulation of ballistic armor with different grade of material becomes the better option to optimize and design the composite armor with less weight and affordable cost.

Some theoretical aspects of ballistic protection testings of composite armors concerning test methods and criteria of armor efficiency estimation, have been considered. The experimental results of performed ballistic tests of the composite ceramics/metal armors, depending on composite armor type, bullet type and target (composite armor) distance have been presented. The corresponding analysis of test results, concerning ballistic protection effects and ballistic efficiency of the composite armors, have been also given.

In this work, new generation higly druable ballistic composite matterial has been investigated. In additon some theoretical aspects of ballistic protection testings of composite armors concerning test methods and criteria of armor efficiency estimation, have been considered. The experimental results of performed ballistic tests of the composite ceramics/metal armors, depending on composite armor type, bullet type and target (composite armor) distance have been presented. The corresponding analysis of test results, concerning ballistic protection effects and ballistic efficiency of the composite armors, have been also given.

Keywords: Armor, Ballistic test, Bullet, Composite armor.

ÖZET

YENİ NESİL UHDPE MALZEMELERİNİN BALİSTİK PERFORMANSLARININ İNCELENMESİ

Zuhair Omar Ahmed
Yüksek Lisans Tezi, Makina Mühendisliği Anabilim Dalı
Tez Danışmanı: Dr.Öğr.Üyesi Halil Ibrahim YAVUZ
Ekim 2018, 81 Sayfa

Bu çalışmamızda kompozit malzemelerin önemli faktörlerinden olan hafiflik ve kalınlık dikkate alınarak daha dayanıklı ve daha dirençli olacak şekilde olabilecek en ince ve hafif hale getirilmeye çalışılmıştır.

Bu kompozit malzemelerin muadillerine nazaran daha az karmaşık modelleme ihtiyacından dolayı daha az bir maliyet ile modellemeleri yapılmıştır. Farklı değerlerde çok sayıda modelleme yapılarak testleri tamamlanmıştır. Burdan da görüleceği üzere daha hafif ve daha ince olmasından dolayı daha uygun maliyetler ile başarılı sonuçlar elde edilmiştir. Balistik koruma için uygulanan metotlar ve yöntemler test aşamalarında uygulanmış ve başarılı sonuçlar elde edilmiştir. Kompozit malzemeye uygulanan testlerin analiz sonuçları içerikte sunulmuştur.

Bu çalışmada, yeni nesil yüksek derecede dayanıklı balistik kompozit maddeler incelenmiştir. Ayrıca, kompozit zırhların test metotları ve zırh verimi tahmini kriterleri ile ilgili balistik koruma testlerinin teorik yönleri ele alınmıştır. Kompozit seramik / metal zırhların kompozit zırh tipine, mermi tipine ve hedef (kompozit zırh) mesafesine bağlı olarak gerçekleştirilen balistik testlerin deney sonuçları sunulmuştur. Kompozit zırhların balistik koruma etkileri ve balistik etkinliği ile alakalı test sonuçlarının ilgili analizleri de verilmiştir.

Anahtar kelimeler: Zırh, Balistik test, Kurşun, Kompozit zırh

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2018

Zuhair Omar Ahmed

TABLE OF CONTENTS

Pages

Pages

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

Figure **Page**

LIST OF ABBREVIATIONS

Some symbols and abbreviations used in this study are presented below, along with descriptions.

Symbols	Description
M	Meter
n	Refractive index
kg	Kilogram
g	Gram
L	Liter
P	polyethylene

LIST OF APPENDIX

Appendixes **Page**

1. INTRODUCTION

A typical composite armor is composed of material layers made of fiber laminates, ceramics, rubbers, metals, etc. Most frequently the design variables in a composite armor design are limited to the material selection, order of the layers and the thickness of the layers. Human's protection has been an important issue since the beginning of creation. Throughout the recorded history, there have been various types of material that are utilized as protection garments from injury, such as in battles and other dangerous situations. Thus, different materials were used as body shield; these include animal's skin, as well as wooden shield and metal shield. Since the introduction of the composite materials, a number of the armor systems involving composites have been designed to protect human lives from vital instruments. Recently, the interest is being directed to natural fiber as a ballistic protective fiber due to economic and environmental benefits that are seriously considered in various applications related to automotive, building, furniture, and packaging industries. Friendly materials commonly contribute to reduction in production cost, in addition to its highest possible filling levels. In particular, ballistic embedding represents the necessary issues in this perspective to create reinforce natural fiber (Zainab, 2011).

For providing such a protection, it is essential to create high performance passive, reactive, dynamic, intelligent and active armor technologies with creative armor design concepts. Today, no single material is capable of effectively defeating wide range of threats, and hence, a wide variety of armors have to be developed. The combat effective ness of a tank basically depends on three main factors: fire power, protection, and mobility. The tilt in emphasis has always remained towards firepower but may not remain so in the future when human life will be considered the most precious of all, even in the battlefield. This means that a tank should withstand the firepower from enemy tanks very well. It should withstand artillery, missiles, and mines along with antitank kinetic energy rounds (Madhu, 2011).

Fiber-reinforced composite materials have become important engineering materials used such as marine bodies, aircraft structures and light-weight armor for ballistic protection in military applications. This is due to their outstanding mechanical properties, flexibility in design capabilities, ease of fabrication and good corrosion, wear and impact resistant. Composite Body armor is an item or piece of clothing that is designed to protect the wearer against a variety of attacks. They can be made to stop different types of threats, such as bullets, knives and needles, or a combination of different attacks. There are two types of body armor – soft body armor, which is used in regular bullet and stab proof vests, and hard armor, which is rigid, reinforced body armor, and is used in high risk situations by police tactical units and combat soldiers (Yohannes, 2014).

A composite material consists of two phases one is called reinforcement and other is called matrix. These two phases are separated by distinct interfaces. The most useful properties of composites are high specific strength and specific stiffness, good corrosion resistance and good fatigue resistance. On account of these highly desirable characteristics, composites have rightfully emerged as important engineering materials for applications where weight of the components or structure is an important consideration. Advanced composite materials, typically consisting of reinforcing fibers (e.g. carbon fibers) in a resin matrix (e.g. epoxy), are progressively replacing metals in the transport and defense industries. Due to their high strength to weight ratios, laminated composite materials have found extensive applications in the construction of mechanical, aerospace, marine, protective gear and automotive structures (Puran, 2013).

Ballistic protection equipment, such as a bulletproof vest or helmet, is a soldier’s most important means of preserving life and health. So far, bulletproof vests have mainly been used by law enforcement agencies, but they are now more commonly available to other users (e.g. security workers or the public). Specific items of clothing, such as ballistic vests, should not only perform protective functions, but also should not influence the users’ bodies negatively. The level of discomfort caused by bulletproof vests results from both decreased energy loss from the human body and heat transfer disturbances (inter alia by the secretion of sweat) due to the weight and size of the vest, and the ambient temperature and level of physical effort required by the officer (Magdalena, 2013).

A ballistic armor system consists of several layers. The first layer is usually formed of ceramic materials whose function is to cushion the initial impact of the projectile. This layer must fracture the tip of the projectile dissipating much of the kinetic energy of the projectile fragment mass and improve the distribution of impact pressure on the second layer. The second layer is also called backing and is formed of ductile materials. Its function is to absorb the kinetic energy of the fragments derived from the residual projectile and ceramics by plastic deformation. The most important requirement of the backing is no fail during the initial stages of the penetration process of the projectile, that is, the backing must withstand compressive stresses transferred to the ceramic after impact. Thus, it would prevent the penetration of the shrapnel containing high kinetic energy and would not deform excessively, as this would jeopardize the lives of persons protected by the armor or the integrity of the equipment. It is important to mention that impacts at high speeds (high kinetic energies) are high complexity phenomena that present limited reproduction, because parameters such as the incidence of the projectile on the armor, for example, are extremely difficult to be adjusted or prevented (Silvaat, 2014).

Bullet proof clothing may be categorized as flak jackets, body armor and bullet proof vests. Bullet proof vests are mainly used to protect the wearer from close range hostile fire. Typical bullet proof vests may be concealed inside a normal garment and are capable of protecting the chest, neck and upper back areas of the user from pistol fire. These vests are made from certain materials which are capable of preventing bullet penetration. Flak jackets mainly focus on protecting the body from the fragments of a blast and short distance firing using a pistol. These are used by military personnel. Compared to body armor, flak jackets are lighter in weight and better in comfort. Body armors are used by the military to protect soldiers from heavy fire (Fernando, 2015).

It is a complex but quite interesting to study the ballistic penetration and perforation of fabrics.

Armors, published concise surveys of the analytical models of penetration of projectiles into fabrics materials, which covered the major works that had been published. There are bullet proof plate, ceramic and fabrics composite materials to make the level III bulletproof plates in the world. (Chen, 2018).

2. LITERATURE REVIEW

2.1. Introduction

Coping and survival instincts led to early developments in body armors often taking the forms of protective clothing and primitive shielding devices. Body armors defined as any defensive coverings worn to protect the body from physical attacks have evolved from readily available materials such as animal skins or natural fibers made from thatch, cotton, and silk often woven in textile forms to metals such as copper, steel, and iron used in plate and chainmail forms to the technologically complex armors used by today's armed services and law enforcement. In short, sophisticated weaponry increases threat effectiveness levels, which, in turn, drives the search for enhanced body armors. Recent innovations in materials and manufacturing technology during the 20th century led to the discovery of advanced manmade textile materials (such as nylon, fiberglass, Kevlar, and many other synthetic fibers) that have provided body armor with extraordinarily improved ballistic protection levels at a significantly reduced weight a potent combination for enhancing the effectiveness and mobility of military troops, law enforcement officers, and security personnel. While those same demands (increased protection at decreased weight) continue today, it is recognized that future improvements will be increasingly difficult to achieve because the financial costs associated with developing new fibers are becoming cost prohibitive and the time to market for their commercialization remains long term (Cavallaro, 2011).

Weight is a key factor in the armor design for the ballistic protection of moving systems such as vehicles, aircrafts and personnel of security and defense corps. Nowadays, the state of the art lightweight armor to defeat armor piercing (AP) projectiles is a ceramic/composite one, usually a boron carbide tile backed by aramid or polyethylene panels. Design optimization of ceramic/composite armors is a complex task due to the high number of variables controlling the penetration process of projectiles into the target. Therefore, the traditional method of armor designing based exclusively on firing tests is expensive when used with composite armors. It has the added disadvantage that the results are hardly extrapolated to configurations other than those tested. An alternative method is the simulation of the ballistic impact by numerical or analytical models. Numerical simulation is performed by means of hydro codes that integrate the differential equations of the mechanics of continuous media using finite differences or finite elements.

Analytical models simulate the impact process by assuming simplifying hypotheses to derive the projectile equations of motion. Analytical simulation is fast, although less accurate than numerical simulation. Armor design optimization is better accomplished by a clever utilization of both ways. Anyway, experimental validation of the solution achieved must be carried out by actual firing tests. In the last decade, the Department of Materials Science of the Polytechnic University of Madrid has developed both numerical subroutines for dynamic behavior of ceramic/composite targets implemented in commercial hydro codes as well as analytical models of ballistic impact onto ceramic-composite armors (Sanchez, 1998).

2.2. History of Body Armor

The full suits of armor, or breast plates actually stopped bullets fired from a modest distance. The front breast plates were, in fact, commonly shot as a test. The impact point would often be encircled with engraving to point it out. This was called the "proof". Metal armor remained in limited use long after its general obsolescence. Soldiers in the American Civil War (1861-1865) bought iron and steel vests from peddlers (both sides had considered but rejected it for standard issue). The effectiveness of the vests varied widely some successfully deflected bullets and saved lives but others were poorly made and resulted in tragedy for the soldiers. In any case the vests were abandoned by many soldiers due to their weight on long marches as well as the stigma they got for being cowards from their fellow troops.

In 1538, Francesco Maria della rovere commissioned Filippo Negroli to create a bulletproof vest. In 1561, Maximilian II, Holy Roman Emperor is recorded as testing his armor against gun-fire. Similarly, in 1590 Sir Henry Lee expected his Greenwich armor to be "pistol proof". Its actual effectiveness was controversial at the time. One of the first examples of commercially sold bulletproof armor was produced by a tailor in Dublin, Ireland in the 1840s (Williams, 2003).

Body armor or personal armor is protective clothing, designed to absorb and deflect slashing, bludgeoning and penetrating attacks by weapon. The oldest known Western armor is the Dendra panoply, which is full-body armor made of bronze plates. Dating from the Mycenaean Era around 1400 Before Christ. Mail, also referred to as chainmail, and is made of interlocking iron rings, which may be riveted or welded shut. Moreover, eastern armor has a long history, beginning in Ancient China. In East Asian history laminated armor such as lamellar, and styles similar to the coat of plates, and brigandine were commonly used. Later, gradually small additional plates or discs of iron were added to the mail to protect vulnerable areas. By about 1400 the full harness of plate armor had been developed in armories of Lonbardy and therefore heavy cavalry dominated the battlefield for centuries in part because of their armor. In the early 15th century, small "hand cannon" first began to be used combination with Wagenburg tactics, allowing infantry to defeat armored knights on the battlefield. Afterwards, there was a 150 year period in which better and more metallurgically advanced steel armor was being used, precisely because of the danger posed by the gun.

By the 15th century Italian armor plates were almost always made of steel and in Southern Germany armorers began to harden their steel armor only in the late 15th century. They would continue to harden their steel for the next century because they quenched and tempered their product which allowed for the fire-gilding to be combined with tempering (Pyke, 2015).

Over the centuries, different cultures developed body armor for use during combat. Mycenaeans of the sixteenth century B.C. and Persians and Greeks around the fifth century B.C. used up to fourteen layers of linen, while Micronesian inhabitants of the Gilbert and Ellice Islands used woven coconut palm fiber until the nineteenth century. Elsewhere, armor was made from the hides of animals: The Chinese as early as the eleventh century B.C. wore rhinoceros skin in five to seven layers, and the Shoshone Indians of North America also developed jackets of several layers of hide that were glued or sewn together. Quilted armor was available in Central America before Cortes, in England in the seventeenth century, and in India until the nineteenth century. Mail armor comprised linked rings or wires of iron, steel, or brass and was developed as early as 400 B.C. near the Ukrainian city of Kiev.

Ballistic nylon was the standard cloth used for bulletproof vests until the 1970s. In 1965, Stephanie Kwolek, a chemist at Du Pont, invented Kevlar, trademark for poly-para-phenylene terephthalamide a liquid polymer that can be spun into aramid fiber and woven into cloth. Originally, Kevlar was developed for use in tires, and later for such diverse products as ropes, gaskets, and various parts for planes and boats. In 1971, Lester Shubin of the National Institute of Law Enforcement and Criminal Justice advocated its use to replace bulky ballistic nylon in bulletproof vests. Kevlar has been the standard material since. In 1989, the Allied Signal Company developed a competitor for Kevlar and called it Spectra. Originally used for sail cloth, the polyethylene fiber is now used to make lighter, yet stronger, nonwoven material for use in bulletproof vests along-side the traditional Kevlar (Naveen, 2016).

Throughout recorded history, military personnel have used various types of materials to protect themselves from injury during combat. This protective clothing (or body armor) has progressed from rudimentary leather protection to mail and full-plated suits of armor, and more recently, ballistic cloth (i.e., Kevlar). Although creating stab- and bulletproof material was once the primary objective of body armor developers, the increasingly sophisticated weaponry employed in modern warfare promotes the need for even greater levels of protection for military personnel (Brianna, 2011).

As in all life-threatening situations, law enforcement personnel and first responders are the first line of protection, and hence personnel protective materials such as helmets, ballistic chest shields, boots, etc., occupy a prominent role in the front line of defense. Not only such materials are important in civilian theaters, these are extremely vital for war fighters in battlefields. Ever since the start of Iraq war, more than 4663 soldiers have lost their lives. Although creating stab- and bulletproof material was once the primary objective of body armor developers, the increasingly sophisticated weaponry employed in modern warfare promotes. It has been reported that majority of deaths in the recent Iraq war has been due to hostile firing and improvised explosive devices (Arvind, 2013).

2.3. Bulletproof Technique

A special group of light body armors are concealed bulletproof vests. A key requirement for these vests, which are worn under clothing, is functional deformation. This term refers to sufficient deformability for the intended applications. This definition can refer to ceramic-based ballistic inserts. As new types of ammunition with increased penetration capabilities appear on the market there is a demand for development of special concealed body armor which will combine excellent ballistic properties of advanced ceramic materials applied in zones, with ability to deform and adjust its shape to the body of the user. The vest must, at the same time, have the lowest possible weight. A typical multi-layered bulletproof vest construction is shown in Figure 1 (Marcin, 2014).

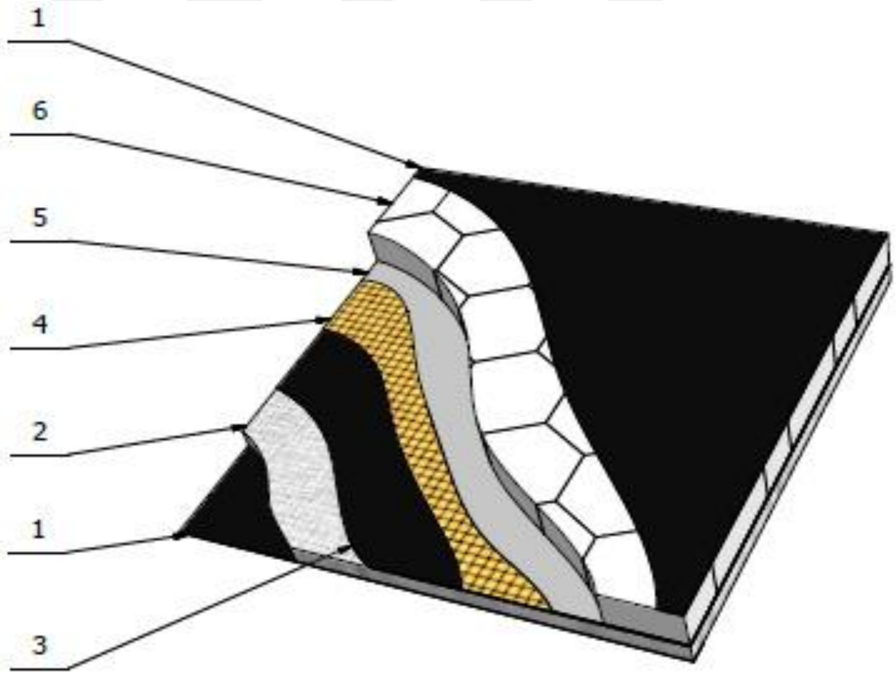


Figure 1. Bulletproof vest construction, 1. Vest outer cover, 2. Soft backing layer,3. Hard ballistic insert outercover, 4. Inner ceramic carrier, 5.Adhesive layer, 6.Ceramic tile layer.

The damage of material subjected to high velocity impact can be divided into four types: flexural, perforation, penetration and spalling Figure 2. In general, ‘no perforation or complete penetration’ is the main requirement for a bulletproof panel to pass most of the standardized tests. However, in actual practice, beside from the perforation, flying debris such as spalling or scabbing, and bullet ricocheting can also cause unexpected damages. In order to make the buildings safer and prevent the secondary damage to occur, the bulletproof panels must not only prevent complete penetrating, it must also maintain its integrity to keep the hazardous debris to minimum. Therefore, the objective of this research is to develop the bulletproof concrete panel that is capable of preventing perforation, bullet ricocheting and concrete spalling by optimizing combinations of different material with different thickness the satisfy the above requirements. Concrete is a brittle material, when subjected to impacted loading, severely broken and spalling at the front and back surfaces are often observed. To improve the brittleness, short fibers were mixed into concrete (fiber reinforced concrete, FRC). With the ability of fibers to bridge across the cracks, the impact resistance of FRC is much more superior to that of plain concrete (Buchit, 2017).

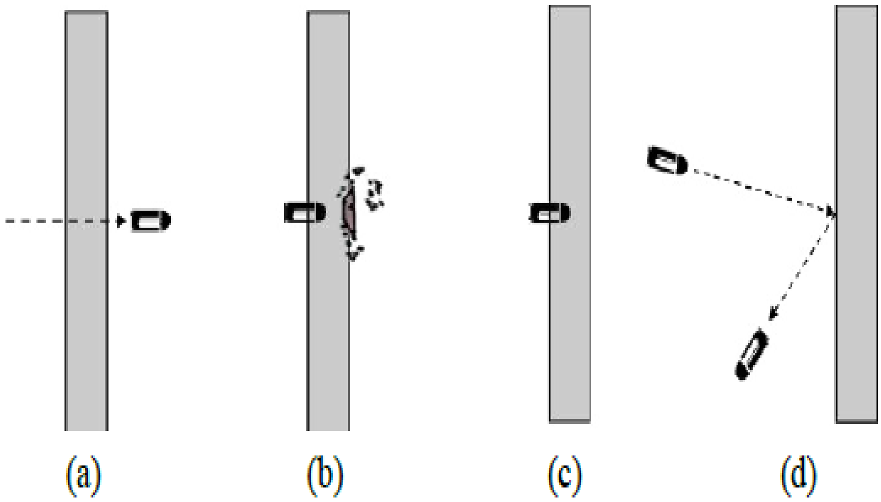


Figure 2. (a) perforation, (b) spalling, (c) penetration, (d) ricocheting.

Protective materials gain large acceptance in defense related areas. One of these areas is the personal protection where a soft vest is used. The basic requirements for the soft vest are ballistic performance, providing comfort for the user, a light weight, and cost-effectiveness. To fulfill these requirements, the important factors are high-performance fiber, fabric formation and layered structures. It is necessary to understand the mechanism of yarn pull-out and the role of yarn pull-out friction in the fabric to enhance ballistic performance. Yarn pull-out is defined as one end of the yarn pulled out of the fabric structure by the motion of the bullet penetrates. The force required to pull the yarn from the fabric structure is the sum of the frictional forces between the yarns sets at all the intersecting points. Several materials are used in form of woven fabrics, knitted fabrics and tri axial fabrics. In this work several samples were made of the following fabrics with the specifications given in Figure 3 (Magdi,2015).

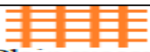
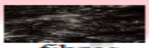
Fabric no	Fabric Type	Material	Weave Yarns per cm	Yarn count tex	Fabric weight (gm/m^2)
1	 Plain weave	100% Cotton	20ends/cm, and 20picks/cm	Warp =11.8 Weft =19.5	85
2	 Plain weave	kevlar	15ends/cm, and 15picks/cm	200	385
3	 Single Jersey knitted 16% LYCRA	Polyester textured continuous filament yarn	15 wales/cm 16.2 courses/cm	20	200
4	 Triaxial Basic Weave	Polyester	Open Basic 3.6 X3.6 X 3.6	144	166
5	 Triaxial Basic Weave	Para-aramid ® 29	Open Basic 3.6 X3.6 X 3.6	167	196.7
6	 Triaxial Basic Weave	victran	Open Basic 3.6 X3.6 X 3.6	140	199
7	 fibres	Continuous filament Carbon fibers	(type M46JB)(12000-50B)		

Figure 3. Material Specifications.

2.4. Literature Summary

Zoran Odanović and Biljana Bobić study and investigations of composite ceramic/metal armors and determination of appropriate protection level regarding different projectile caliber (common and armor-piercing projectile), the composite armor ballistic efficiency is presented in this paper. Protection effects of ceramics and different backing metal materials were analyzed during the testing's.

Saihe defeat capability of ceramic tiles can be significantly improved by wrapping the tiles in a thin flexible membrane such as glass fiber tape. Following these experiments, a systematic series of tests have been performed to study the ballistic failure of bare and membrane restrained Al_2O_3 and SiC tiles. A comparative study of restraint by E-glass/epoxy, carbon-fiber/epoxy and Ti-3%, Al-2.5% Valloy has been performed. Also the effects of varying the thickness of the restraining membrane and different configurations were studied. Experiments were devised with an emphasis on the observations of the failure mechanism's during penetration. Well controlled experiments and direct observation through high-speed photography and flash radiography were used to characterize the essential processes involved in the interaction between high velocity penetrators and ceramic tiles (Zainab, 2011).

Figure 4. Final Kevlar29 - ramie composite (the front panel from the TSP).

Found the methods for fabricating composite laminates using three materials with accurate descriptions of the specific tasks. The advancement in designing a new composite constructor is embodied in the composite compounds arrangement and the tactical ways that are depended on the assembled layers. Meanwhile, the target geometry is a sensitive point in this investigation, and the adjacent panels have the responsibility to reduce the projectile kinetic energy. The target preparation processes include composite preparation and geometry of the target. Hence, the composite was constructed from the Kevlar and ramie layers, since the target area was 15 × 10 cm. In particular, the ramie and Kevlar layers were arranged and impregnated using polyester resin to have the interfacial linkage between the layers, as illustrated in Figure 3.

Have worked to demonstrate a new technique for FE simulation, based on LS-Dyna FE code, for normal penetration of cylindrical projectiles onto the ceramic–composite targets (Feli,2011). In this model the above mention assumes is modified. For describing the fragmentation of ceramic front plate the Johnson–Holm quest continuum based plasticity model is used. In this model the brittle failure, effects of high pressure and strain rate and large deformation of ceramic material under high velocity impact is considered. For modeling the composite material, the composite damage model in LS-Dyna FE code is chosen, which contains three failure criteria including fiber fracture, matrix cracking or compressive failure. Also the effects of work hardening, strain rate, erosion, and temperature is considered in the tungsten projectile material. Furthermore, the erosion model including failure in material models and deletes the elements from calculations is used. The values of residual velocity and perforation time are compared with the results of other researchers. In addition, the performance of ceramic/composite armor subjected to ballistic impact is investigated (Siriphala, 2012).

Study to verify an FE model employed to predict the resistance of an armor plate against bullet impact. An Eulerian FE solver where the material is able to flow through structure grids was employed for the simulation of bullet impact on an armor. This type of computation is suitable to handle the model with a severe distortion.

The study has explored Textile vests may be augmented with metal (steel or titanium), ceramic or polyethylene plates that provide extra protection to vital areas. These hard armor plates have proven effective against all handgun bullets and a range of rifles. These upgraded ballistic vests have become standard in military use; as soft body armor vests are ineffective against military rifle rounds. Corrections officers and other law enforcement officers often wear vests which are designed specifically against bladed weapons and sharp objects. These vests may incorporate coated and laminated para-aramid textiles or metallic components (Fernanda, 2015).

Based on the aforementioned considerations, the ballistic performance of armors composed of a front ceramic and an intermediate composite as well as a back aluminum layers was investigated in terms of depth of penetration into clay witness simulating a personal body. Ballistic tests were conducted in MAS with a front Al_2O_3 based ceramic tile. As the following intermediate layer, lighter jute fabric reinforced epoxy composite plates were compared (same thickness), to plain epoxy plates and Kevlar™. The contribution of each separated material was also assessed by individual ballistic tests. The fracture aspects of the different types of intermediated layer materials were analyzed by scanning electron microscopy (Phil, 2015).

Found that armor is designed for the defeat of a specific threat regime, it then requires testing to confirm that it meets these relevant protection requirements. Therefore, a test method or standard needs to be chosen which is relevant to the requirement for the protection. This decision regarding the test method or standard is often not as simple as it may initially seem. The conflict within the decision-making process is often due to a difference between the reality of the threat and what is available to use within the available test methods or standards (Naveen, 2016).

An overview to make bulletproof vest first of all polymer is prepared then with the help of polymer panel cloth is made. After that cutting of panel cloth starts. And then the sewing of panel cloth starts.to provide more protection to bulletproof vest there are pouches provide in it. In which we can put plats which are made of high quality ceramic. These plates upgrade the level of bulletproof vest.

Has worked on the material used for modeling of composite body armor was Kevlar-29 fiber and polyester resin. The simulation result for 20 layers (10mm thick) of woven Kevlar-29 fiber with polyester resin as a matrix shows that there is no penetration through the modeled composite body armor panel by a projectile of 7.62x39mm bullet impact load at 10 and 50 meters and the weight of modeled composite body armor was 0.9 kg. There is also bullet resistant body armor that modeled as integral armor from16layers and 5mmthick sheet metal steel and it weighs about 1.5 kg. These results were validated against published data and good correlation was observed. By considering the current thickness and weight of modeled and simulated bullet resistant composite body armor there is a recommendation thrown to any researcher to reduce the weight in terms of thickness in any available technique.

Have found the next technology advancement, a replacement in body armor. Graphene is a single atomic layer of graphite, which is composed of a hexagonal lattice of carbon atoms. It exhibits properties of extreme strength and is extremely lightweight. Engineers have begun testing this material's successfulness in bulletproof vests. We will delve into the strengths and weaknesses of graphene in the construction of bulletproof vests for stopping projectiles, as well as the testing that has been done on the material (Colin, 2017).

Researched having been conducted in military populations, and despite the increasing use of body armor systems by LEO, published research that has examined the extent to which body armor can impact the performance capabilities of LEO during physically demanding occupational tasks has not been comprehensively and critically reviewed. The aim of this systematic review of the literature was therefore to identify and critically appraise the methodological quality of published studies that have investigated the impacts of body armor on task performance in tactical populations, and to synthesize and report key findings from these studies to inform law enforcement organizations.

Had to analyses the composite material for bullet-proof material we will now give a brief introduction regarding ballistic material. The purpose of the ballistic protective materials is not to just stop the speeding bullets but to protect the individual from fragmenting devices as well, i.e. from grenades, mortars, artillery shells, and improvised explosive devices. We should note that the injury caused to the civilians is mainly due to two factors high velocity bullets from rifles, machine guns which are mainly shot from a long range. Low velocity bullets from hand guns which are shot from close range (Anish, 2017).

Used the Taguchi method to improve the quality of engineering, the experimental steps outlined below, material selection: According to the source material's availability and quality. Control factors selection: Basically three choices controllable factor, to predicted its quality characteristics under impact. Each factor have 2~3 levels. Recognizing the quality characteristics and the loss function. Selecting the appropriate orthogonal array for design experiments, and execute the impact test. Formulate the data for the signal to noise ratio, quality characteristics and

ANOVA analysis to find the best combination of factors. Making the best specimen combination testing to verify the best combination results (Girish, 2017).

Investigated on the K-29 aramid fiber is used as reinforcement filler for epoxy based polymer composite. Samples are prepared as laminated composite panels under room temperature and the tensile strength, flexural strength and impact strength of composite samples are investigated. All tests were performed according to their respective American Society of Testing and Methods (ASTM) standards.

Have been worked, AUTODYN-2D is used to evaluate and compare the impact resistance capabilities of three different ceramic materials against armor piercing bullets of two different types. Impact bearing capability of four different thicknesses of Alumina (99.7%), Alumina (99.5%) and Silicon carbide plates was simulated against armor piercing projectiles with steel 4340 and tungsten carbide cores.

3. MATERIALS AND METHODS

3.1. Bulletproof Materials

A composite material is defined as a material comprising of two or more chemically and or physically distinct constituents (phases) combined on a macroscopic scale. The constituents present in the composite material retain their individual identities and properties, but together they produce a material system, the properties of which are designed to be superior to those of the constituent materials acting independently. A composite material consists of two phases one is called reinforcement and other is called matrix. These two phases are separated by distinct interfaces. The most useful properties of composites are high specific strength and specific stiffness, good corrosion resistance and good fatigue resistance. A Bullet proof consist of a panel a vest shaped sheet of advanced plastic polymer that is composed of many layers of either Kevlar, spectra shield, twaron or dyneema boron (Sujith N S et al. 2015).

3.2. Materials Using in Armor Body

3.2.1. Polyethylene

Polyethylene (PE) is the most large-scale produced polymer: its production volume amounts to about 100 million t per year. A great number of PE types and grades are known: linear and branched PE, polyethylene with various molecular mass and various molecular mass distribution, copolymers of ethylene and olefins with different content of olefin as well as with different character of chemical and composition al distribution of olefin within the macro molecule etc. However, only separate PE grades those exhibit special physic mechanical properties, could be considered belonging to constructional polymers (Selyutin, 2010).

Figure 5 demonstrates data concerning the relative a brad ability of different materials (Kurtz, 1999). One can see that the a brad ability of UHMWPE is more than five times lower than the a brad ability of teflon.

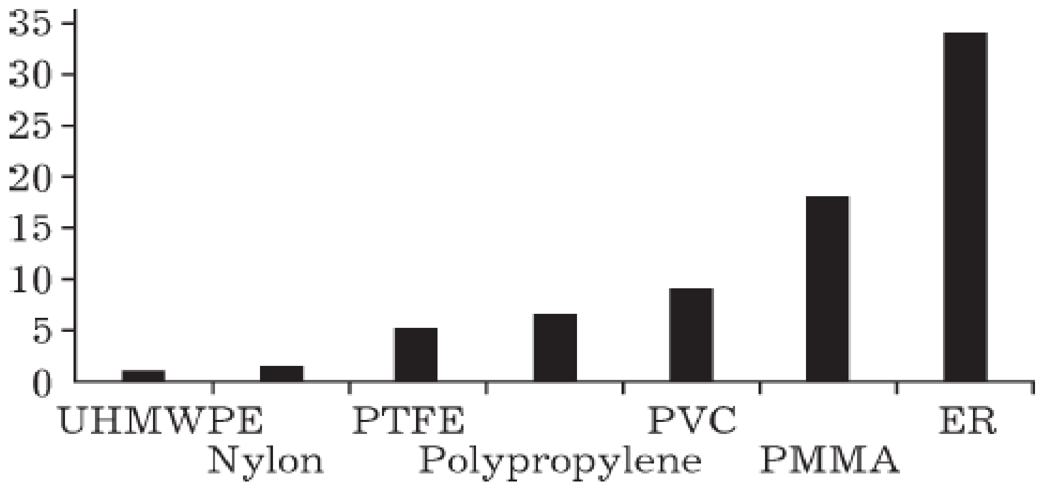


Figure 5. Relative a brad ability of different materials: UHMWPE . ultra high molecular weight polyethylene, PTFE. polytetrafluoroethylene (Teflon), PVC. polyvinylchloride, PÌÌÀ. polymer thy l methacrylate, ER. epoxide resin.

3.2.2. Ceramic

The low density and the high hardness of ceramics often make the use of them a better alternative in protection solutions than armor grade steel. Some of the important material parameters of armor ceramics are discussed in this section, together with an introduction to the three most used ceramics for armor purposes. Main points on armor ceramic: The most commonly used ceramics for armor purposes are aluminum oxide (Al_2O_3), silicon carbide (SiC) and boron carbide (B_4C). Al_2O_3 is usually the most economical alternative, but the final protection solutions with Al_2O_3 are heavier, since Al_2O_3 has the highest density and the lowest ballistic efficiency of the three ceramic types. B_4C is the hardest ceramic, but at high impact pressures an armor phization process weakens the ceramic. This is problematic when the threat is an armor piercing projectile at high velocity. SiC does not have the armor phization issue, but the density of SiC is higher than for B_4C. Low porosity in the ceramic generally results in better ballistic performance. Ceramics with small grain size usually performs better than ceramics with larger grainsizes. The production method influences the properties of the ceramic; hot-pressing often results in a harder ceramic optimal for single-hit, while reaction bonding often produce ceramics with better multi-hit performance. There is no clear correlation between the quasi-static mechanical properties and the ballistic behavior of ceramics. However, some parameters such as the hardness, the fracture toughness and the elastic modulus are expected to have an influence (Dennis, 2015).

3.2.3. Cobalt

WC-Co and tungsten alloys may fall short in one aspect of performance compared to their principle competitor, DU, however they do not have the same health, safety and environment barriers to their development (Nicola, 2005).

3.2.4. Graphene

Extra-large surface-to-volume ratio renders graphene a highly flexible morphology, giving rise to intriguing observations such as ripples, wrinkles and folds. Such a malleable nature of graphene makes it a potential candidate material for nanoscale origami and kirigami, a promising bottom-up nano manufacturing approach to fabricating nano-building blocks of desirable shapes beyond conventional material preparation techniques. The success of graphene origami and kirigami hinges upon precise and facile control of graphene morphology, which remains as a significant challenge. Nonetheless, recent progress in patterning graphene with atomic-scale precision has further paved the way toward achieving graphene origami and kirigami in a programmable fashion (Deji, 2017).

3.2.5. Polyester

Generally, the basic aim of armoring is to ensure maximum ballistic protection against high velocity projectiles of different type and armor-piercing (AP) ammunition. The combinations of extremely hard metallic and non-metallic materials offer effective ballistic protection. Composite armoring materials are two-layered and multi layered combinations of aluminum, steel, titanium, ceramics, epoxy/glass composite, resins etc.. The protection principle is based on different hardness of composite armor components. Facing side, usually very hard, is intended for crushing and exploding of projectile, thus reducing its penetration power. Composite armor backing plate, possessing high deformability and plasticity, absorbs the projectile kinetic energy. Generally, two layered composite armor combinations are: Ceramics or high hardness steel as a facing material, and aluminum armor or mollified armor steel (Zoran, 2003).

3.3. Laboratory

In our study of this research we used several devices in this test to prepare armor sample, in the following is a simplified explanation of these devices.

Figure 6. Laboratory workspace.

3.3.1. Vacuum device

This device is used to pull the air out of the sample and get one piece coherent and strong homogeneous, the device shall be operated for at least five minutes according to the sample used and represented by the thickness and materials used to manufacture the armor and its size. After the finishing the vacuum stage the sample is placed in the electric oven, Figure 7 represents vacuum device.

Figure 7. Vacuum device for vacuuming.

3.3.2. Discharge box

After completion of the manufacturing phase of the armor sample placed inside this container or discharge box and tightly closed is not leakage of air when running the vacuum device, where the vacuum device is connected with the discharge box, Figure 8 shows the discharge box.

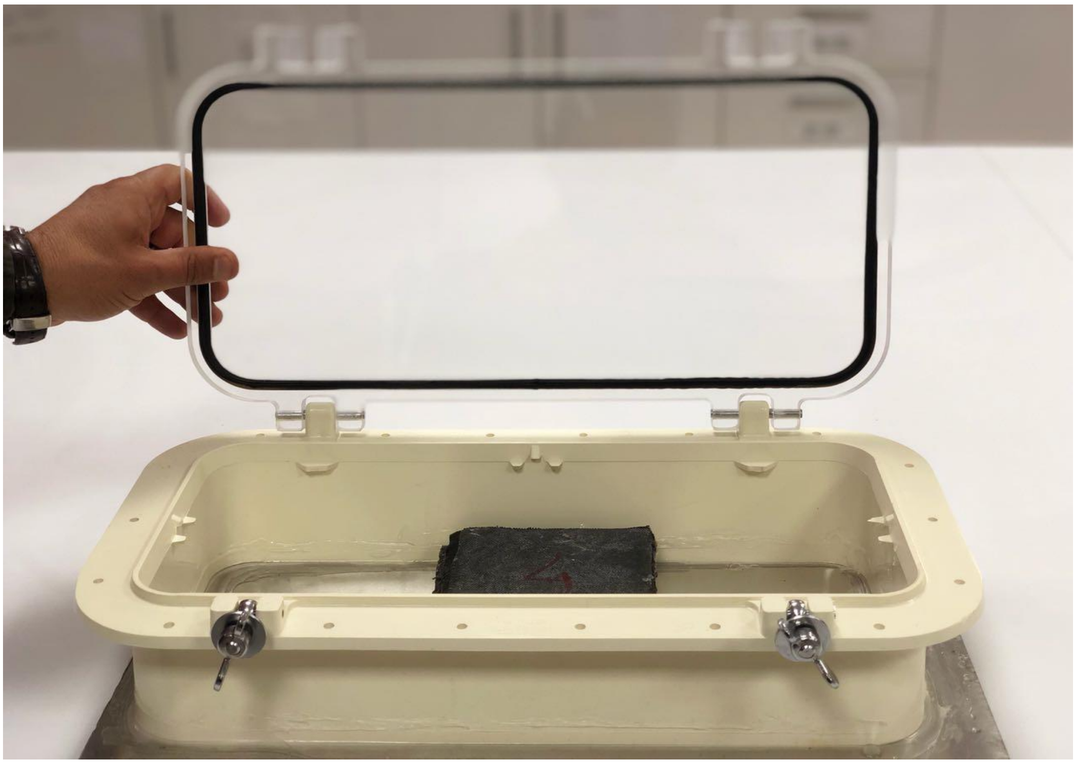


Figure 8. Discharge box.

3.3.3. Chemical flask

Used for the formulation mixing and mixing of liquid materials used between polyethylene layers. The flask must be included to find out the amounts added to it for example, polyethylene should be limited in millimeters and the amount of cobalt and graphene is mixed well with continuous stirring within the flask and putting between layers of polyethylene, represents the laboratory flask.

3.4. Components of The Armor Used in This Study

Ballistic nylon (until the 1970) or Kevlar or Spectra (a competitor for Kevlar) or polyethylene fiber could be used to manufacture bullet proof vests. The vests of the time were made of ballistic nylon &supplemented by plates of fiber-glass, steel, ceramic, titanium, doron & composites of ceramic and fiberglass, the last being the most effective**.**

3.4.1. Working principle

When a hand gun bullet strikes body armor, it is caught in a "web" of extremely strong fibers. These fibers absorb and disperse the impact energy that is transmitted to the bullet proof vest from the bullet causing the bullet to deform, otherwise known as a "mushroom". Additional energy is absorbed by each successive layer or material in bullet proof vests until such time as the bullet has been stopped.

Ceramic plates work by locally shattering where the projectile strikes, and are capable of dispersing the energy of the projectile to the point where the bullet has been stopped. Unfortunately, this means that ceramic plates become progressively less capable of stopping additional bullets, and may be rendered unusable after a certain number of hits have been taken.

3.4.1.1.Polyethylene

Considered the basic article in manufacturing armor, where we cut the polyethylene fabric by (10*10 cm) to be sample for weapons test where both are placed from 15 to 20 layers in the construction of the armor as shown in figure. We have conducted many tests on polyethylene fabric of which tensile test and tearing test and impact test, and we studied mechanical and thermal properties, it was very strong and strength in carrying out the tests of the weapons, in the figure below shown the polyethylene fabric and some formation.

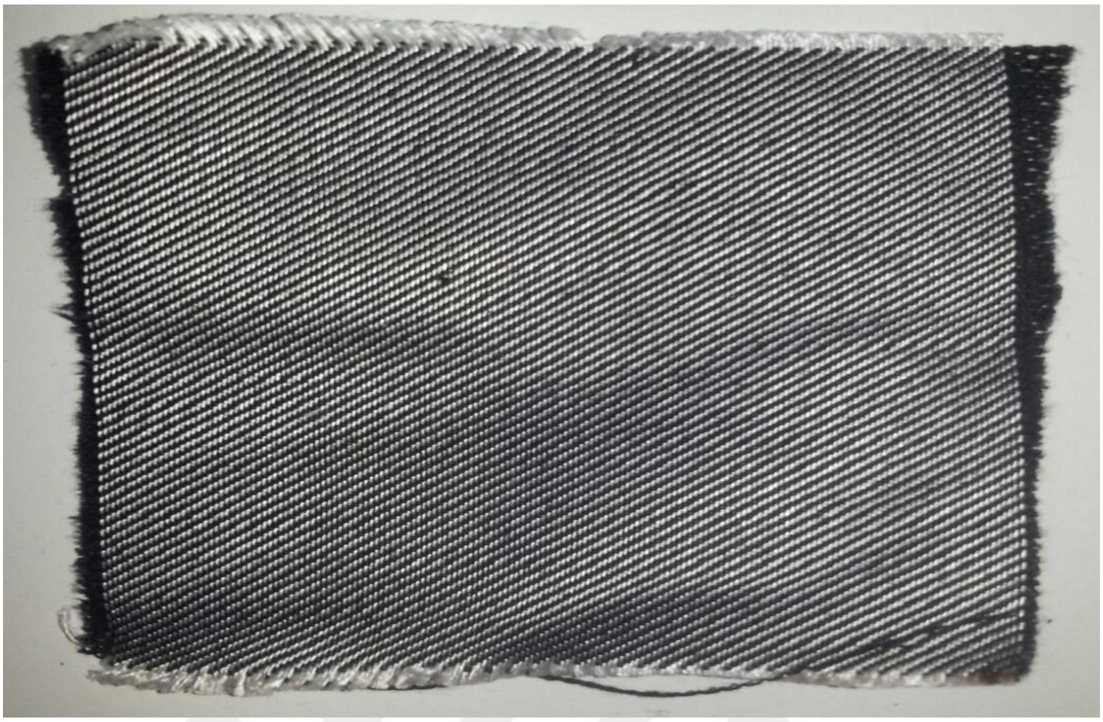


Figure 9. Fabric used in application.

3.4.1.2.Polyester

We used polyester between the layer of polyethylene before mixing with another material like cobalt and graphene, Figure 10 below shows polyester. Polyester is a category of polymers that contain the ester functional group in their main chain. As a specific material, it most commonly refers to a type called polyethylene terephthalate (PET). Polyesters include naturally occurring chemicals, such as in the cutin of plant cuticles, as well as synthetics such as polybutyrate. The material is used extensively in clothing. Depending on the chemical structure, polyester can be a thermoplastic or thermoset. There are also polyester resins cured by hardeners; however, the most common polyesters are thermoplastics. The OH group is reacted with an Isocyanate functional compound in a 2 component system producing coatings which may optionally be pigmented. Fabrics woven or knitted from polyester thread or yarn are used extensively in apparel and home furnishings, from shirts and pants to jackets and hats, bed sheets, blankets, upholstered furniture and computer mouse mats. Industrial polyester fibers, yarns and ropes are used in car tire reinforcements, fabrics for conveyor belts, safety belts, coated fabrics and plastic reinforcements with high-energy absorption. Polyester fiber is used as cushioning and insulating material in pillows, comforters and upholstery padding. Polyester fabrics are highly stain-resistant in fact, the only class of dyes which *can* be used to alter the color of polyester fabric are what are known as disperse dyes. Cotton-polyester blends (polycotton) can be strong, wrinkle and tear-resistant, and reduce shrinking. Synthetic fibers using polyester have high water, wind and environmental resistance compared to plant-derived fibers. They are less fire resistant and can melt when ignited. Polyester blends have been renamed so as to suggest their similarity or even superiority to natural fibers (for example, China silk, which is a term in the textiles industry for a 100% polyester fiber woven to resemble the sheen and durability of insect-derived silk). Polyesters are widely used as a finish on high-quality wood products such as guitars, pianos and vehicle/yacht interiors. Thixotropic properties of spray-applicable polyesters make them ideal for use on open-grain timbers, as they can quickly fill wood grain, with a high-build film thickness per coat. Cured polyesters can be sanded and polished to a high-gloss, durable finish. Liquid crystalline polyesters are among the first industrially used liquid crystal polymers.

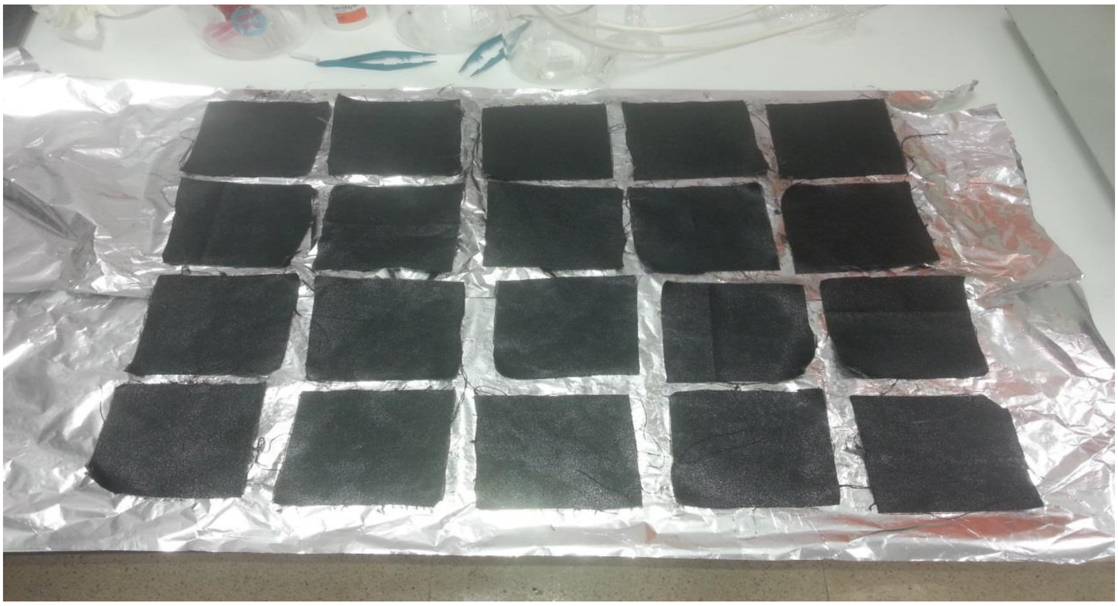


Figure 10. Fabrics made of resin.

3.4.1.3.Cobalt

In the composition of the armor material in this study we used the cobalt liquid, Figure 11 shows the sample of cobalt liquid. Cobalt is a chemical element with symbol Co and atomic number 27. Like nickel, cobalt is found in the Earth's crust only in chemically combined form, save for small deposits found in alloys of natural meteoric iron. The free element, produced by reductive smelting, is a hard, lustrous, silver-gray metal. Cobalt based blue pigments (cobalt blue) have been used since ancient times for jewelry and paints, and to impart a distinctive blue tint to glass, but the color was later thought by alchemists to be due to the known metal bismuth. Miners had long used the name *kobold ore* (German for *goblin ore*) for some of the blue-pigment producing minerals; they were so named because they were poor in known metals, and gave poisonous arsenic-containing fumes when smelted. In 1735, such ores were found to be reducible to a new metal (the first discovered since ancient times), and this was ultimately named for the *kobold*. Today, some cobalt is produced specifically from one of a number of metallic-lustered ores, such as for example cobaltite (CoAsS). The element is however more usually produced as a by-product of copper and nickel mining.

Figure 11. Cobalt used in practice.

3.4.1.4.Graphene

We used graphene material in this study to change the properties of the armor as shown in Figure 12. Graphene is a semimetal with small overlap between the valence and the conduction bands (zero bandgap material). It is an allotrope (form) of carbon consisting of a single layer of carbon atoms arranged in a hexagonal lattice. It is the basic structural element of many other allotropes of carbon, such as graphite, diamond, charcoal, carbon nanotubes and fullerenes. It can be considered as an indefinitely large aromatic molecule, the ultimate case of the family of flat polycyclic aromatic hydrocarbons. Graphene has many uncommon properties. It is the strongest material ever tested, conducts heat and electricity efficiently, and is nearly transparent. Graphene shows a large and nonlinear diamagnetism, greater than that of graphite, and can be levitated by neodymium magnets. Scientists theorized about graphene for years. It had been produced unintentionally in small quantities for centuries through the use of pencils and other similar graphite applications. It was observed originally in electron microscopes in 1962, but it was studied only while supported on metal surfaces. The material was later rediscovered, isolated, and characterized in 2004 by Andre Geim and Konstantin Novoselov at the University of Manchester. Research was informed by existing theoretical descriptions of its composition, structure, and properties. This work resulted in the two winning the Nobel Prize in Physics in 2010 for groundbreaking experiments regarding the two-dimensional material graphene.

Figure 12. Graphene used in application.

3.4.1.5.Ceramic

Finally, we added ceramic material to the armor composition to give us the good properties of the armor materials which is used in this study, as shown in Figure 13. The crystallinity of ceramic materials ranges from highly oriented to semi-crystalline, vitrified, and often completely amorphous (e.g., glasses). Most often, fired ceramics are either vitrified or semi-vitrified as is the case with earthenware, stoneware, and porcelain. Varying crystallinity and electron consumption in the ionic and covalent bonds cause most ceramic materials to be good thermal and electrical insulators (extensively researched in ceramic engineering). With such a large range of possible options for the composition / structure of a ceramic (e.g. nearly all of the elements, nearly all types of bonding, and all levels of crystallinity), the breadth of the subject is vast, and identifiable attributes (e.g. hardness, toughness, electrical conductivity, etc.) are hard to specify for the group as a whole. General properties such as high melting temperature, high hardness, poor conductivity, high moduli of elasticity, chemical resistance and low ductility are the norm, with known exceptions to each of these rules.

Figure 13. Ceramic used in application.

3.5. Armor Composition Results of Study

Materials which are used in this study (polyethylene fabric, polyester, cobalt, graphene, and ceramic) collected together in an organized manner to form a good armor ready for weapons tests on it, and the weapons used are GUN CEN BR2 and SNIPER CEN BR7.

3.5.1. Gun CEN BR2

Properties of this gun which is used in the test study as the following:

1. Mass of bullet 8.0 g
2. Test range 5,0 m.
3. Bullet velocity 400 m/s.

Gun CEN BR2 is shown in the Figure 16.

Figure 14. Pistol of CEN BR2.

3.5.2. Sniper CEN BR7

Properties of this gun which is used in the test study as the following:

1. Mass 9.8 g.
2. Test range 10,0 m.
3. Bullet velocity 820 m/s.

3.5. Improvement Sample

	Class Threat Level	Type of Weapon	Calibre	Ammunition	No of Shots	Velocity (m/s)	Test Range (m)	Spacing (mm)
	BR1	Rifle	.22 LR	L/RN	3	360 +/- 10	10	120 +/- 10
	BR2	Hand Gun	9mm Luger	FJ1/RN/SC	3	400 +/- 10	5	120 +/- 10
	BR3	Hand Gun	.357 Magnum	FJ1/CB/SC	3	430 +/- 10	5	120 +/- 10
	BR4	Hand Gun	.44 Rem Magnum	FJ2/FN/SC	3	440 +/- 10	5	120 +/- 10
	BR5	Rifle	5.56x45	FJ2/PB/ SCP 1	3	950 +/- 10	10	120 +/- 10
	BR6	Rifle	7.62x51	FJ1/PB/SC	3	830 +/- 10	10	120 +/- 10
	BR7	Rifle	7.62x51	FJ2/PB/ HC 1	3	820 +/- 10	10	120 +/- 10
	SG1	Shot Gun	12/70	Solid Slug 3	1	420 +/- 20	10	-
	SG2	Shot Gun	12/70	Solid Slug 3	3	420 +/- 20	10	125 +/- 10

Figure 15. NATO's ballistic armor classification.

We mentioned earlier on the used of weapons including gun and sniper and MG2, the bullet of gun was (9.19 mm), as for HK33 ARMOR PIERCING the bullet was (5.56 mm), as for BORA SNIPER the bullet was (7.62*10 mm) as for MG2 the bullet was (12.7*99mm), and when tested the sample 11 by the MG2 the bulled passed the armor, then we made some improvements add percentage of graphene and we re-tested with success and did not passed the armor by bullet, Figure 16 shows the electric balance measure the graphene for improvement sample.

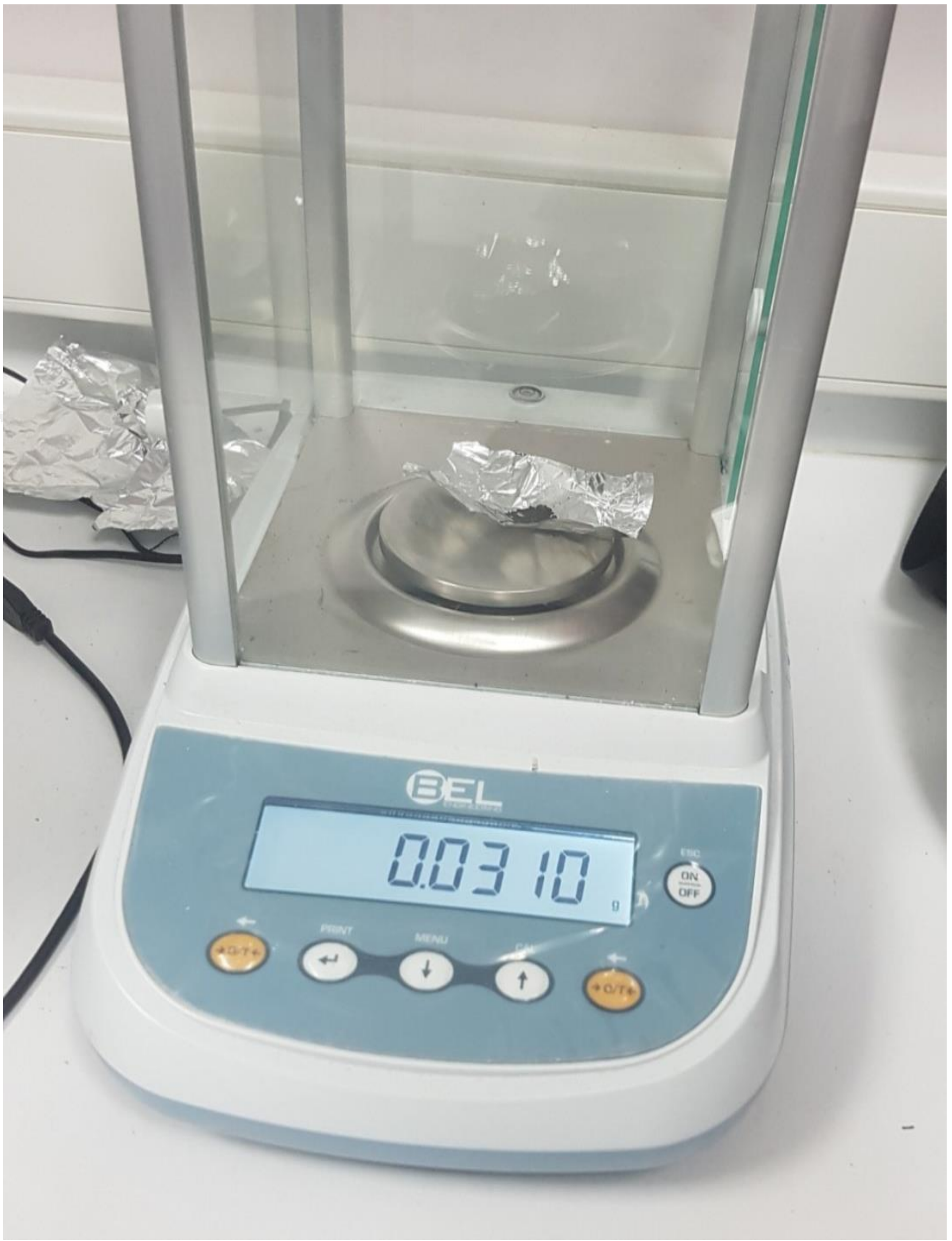


Figure 16. Graphene weight measurement with precision scales.

3.6. Types of Bullets Used in Sample of Armor

In the Figure 17 below shown some types of bullets used in sample of armor which we have done.

Figure 17. Various ammunition.

Figure 18. Size difference between ammunition.

Kevlar and polyethylene fabric which are used in some sample of armor which are made in the laboratory as shown in Figure 19.

Figure 19. Examples of armors.

4. RESULTS

4.1. XRF results of Ceramic Part

Table 1. XRF results of ceramic part

(Chemical Analysis by XRF)	Results
SiO_2	% 65.35
Al_2O_3	% 16.69
Fe_2O_3	% 2.44
CaO	% 3.63
MgO	% 1.35
Na_2O	% 4.59
K_2O	% 4.46
P_2O_5	% 0.30
MnO	% 0.06
BaO	% 0.14
SrO	% 0.15
SO_3	% 0.01
Cr_2O_3	% 0.01
TiO_2	% 0.42
NiO	% 0.01
Rb_2O	% 0.01
ZrO_2	% 0.02
BaO	% 0.14
WO_2	% 0.10
A.Z. (LOI)	% 0.27

According to the results of xrf, the concentration of SiO_2 is the largest. together with the Al_2O_3 concentration. Both oxides are one of the hardest minerals found in nature in the minerals so it seems that the right material has been chosen to meet the lead.

4.2. Apparent Density Total And Open Porosity Test

Table 2. Apparent density total and open porosity test

Test number	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Sample Size	70x70x70	70x70x70	70x70x70	70x70x70	70x70x70	70x70x70
(Apparent density) $kg/m^{3)}$	2640	2639	2638	2636	2638	2640
(Open porosity %)	0.77	0.77	0.74	0.73	0.75	0.77
(Total porosity %)	2.63	2.66	2.69	2.77	2.85	2.63
(Average Values)	(Apparent density kg|m^2) 2639		(Open porosity %) 0.75		(Total porosity %) 2.71	
(Standard Deviation)	1.52		0.02		0.09	

According to Test results of the apparent density total and open porosity, the total density is found as 2656 kg / m^2 the external openness, which may cause the formation of external cracks in the product, is found less than 0.75%. However, the total porosity space in the metaphor is 2.5%.

4.3. Determination of The Slip Resistance By Means of The Pendulum Tests

Table 3. Determination of the slip resistance by means of the pendulum tester (Wet)

Test No	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
(Sample Size) mm	200x100x20	200x100x20	200x100x20	200x100x20	200x100x20	200x100x20
(The value read scale SRV d°)	17	14	13	14	14	13
(The value read scale Rotated 180°)(SRV d°)	18	16	14	13	15	14
(Average Value) (SRV d°)				14.6		

According to Test results of slip resistance on wet conditions, the Average Value (SRV d°) is found as 14.6. In addition, there is a little significant difference between the Rotated and normal pendulum tests, but an increased results found rotated values in the average values of the slip resistance. However there is no significant difference found in dry conditions.

Table 4. Determination of the slip resistance by means of the pendulum tester (Dry Conditions)

Test No	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
(Sample Size)mm	200x100x 20	200x100x 20	200x100x 20	200x100x 20	200x100x 20	200x100x 20
(The value read scale) (SRV d°)	56	58	59	59	57	58
(The value read scale Rotated 180º) (SRV d°)	59	57	59	60	58	58
(Average Value) (SRV d°)			58			

4.4. Determination of Water Absorption Coefficient By Capillarity

Table 5. Determination of water absorption coefficient by capillarity

Test No	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
(Sample Size)mm	68.14x71.44	71.23x68.20	69.68x71.33	69.57x71.08	69.34x70.70	71.04x70.42
(Results) ($g/m^2.s$ 0.5)	1.05	1.05	1.03	1.13	1.12	1.90
(Average Value) ($g/m^2.s$ 0.5)	1.21					
(Standard Deviation)	0.34					

In the light of determination of water absorption coefficient by capillarity test average water absorption coefficient is determined as 1.21 g/m^2

4.5. Specific Gravity of Solids By Gas Pycnometer

Table 6. Specific gravity of solids by gas pycnometer

Test number	**Test 1**	**Test** 2	**Test** 3	**Test** 4	**Test** 5
(Density)(g/cm³)	2.7278	2.7264	2.7139	2.7088	2.7105
(Sample Volume) (g/cm³)	18.0608	18.0699	18.1534	18.1875	18.1761
(Average Value)(kg/m³)			2711		
(Standard Deviation)			0.0142		

In the light of table 4.6, Average Specific Gravity is determined as 2711 ±0.0142 *kg/m³*

4.6. Determination of Water Absorption at Atmospheric Pressure

Table 7. Determination of water absorption at atmospheric pressure

Test No	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
(Sample Size)mm	70x70x70	70x70x70	70x70x70	70x70x70	70x70x70	70x70x70
(Results)%	0.3	0.3	0.3	0.3	0.3	0.3
(Average Value)%			0.3			
(Standard Deviation)			0			

In the light of table 4.7, Average water absorption coefficient at atmospheric pressure is determined as 0.3 ±0*kg/m³*

4.7. Determination of Compressive Strength

Table 8. Determination of compressive strength

Test No	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
(Sample Size)mm	70.4x71.2	69.1x70.6	71.3x70.4	71.2x70.4	69.9x70.2	70.6x71.6	71.8x69.4	70.0x72.1	70.6x72.4	69.9x71.1
(Breaking Load) (KN)	746.7	788.4	753.5	716.4	781.1	627.5	807.5	827.0	743.1	742.9
(Results) (MPa)	149	162	150	143	160	124	162	164	145	150
(Average Value)(MPa)	151									
(Standard Deviation)	12.14									

According to results of table 4.8 of table 4.6, Average compressive strength is determined as 151± 12.14 MPa. This value not enough for meet the bullet or we cannot see bulletproof effect. Therefore, we need make a composite for get higher compressive strength.

4.8. Determination of Flexural Strength Under Constant Moment

Table 9. Determination of flexural strength under constant moment

Test No	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
(Width) mm	60	60	60	60	60	60	60	60	60	60
(Thickness) mm	60	60	60	60	60	60	60	60	60	60
(Sample Size) mm	360	360	360	360	360	360	360	360	360	360
(Distance between lateral supports mm)	300	300	300	300	300	300	300	300	300	300
(Deviation from perpendicularity)	0.6	0.5	0.7	0.6	0.5	0.6	0.6	0.7	0.5	0.6
(Breaking Load) (kN)	13.45	12.80	12.03	13.62	13.12	12.92	13.55	12.93	13.83	13.04
(Results) (MPa)	23.99	21.33	20.08	22.70	21.87	21.53	22.88	21.55	23.05	21.73
(Average Value) (MPa)	22.04									
(Standard Deviation)	1.10									

According to results of table 4.9, Average flexural strength under constant moment is found as 22.04± 1.1 MPa. As before we discuss table 4.8 results, this value not enough for meet the bullet or we cannot see bulletproof effect. Therefore, we need make a composite for get higher compressive strength.

4.9 Ballistic Test Results of Some Sample Armor Tests.

NUMBER	HDPE AMOUNT	PURE HDPE WEIGHT (g)	SPREAD POLYESTER (ml)	POLYESTER WEIGHT (g)	GRANITE NO	GRANITE WEIGHT (g)	GRANİT THICKNESS (mm)	COBALT(g)	GRAPHENE	TOTAL WEIGHT (g)	TYPE OF WEAPON	TYPE OF BULLET (mm)	RESULT
1	20	74.72	100	77.28	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	152	GUN	9.19	PASS
2	40	150.34	200	173.66	ABSENT	ABSENT	ABSENT	Full Cover (3,8339)	ABSENT	324	GUN	9.19	HOLD
3	20	80.04	100	87.96	ABSENT	ABSENT	ABSENT	Full Cover (3,8339)	0,02g 2L 150g/ml	168	GUN	9.19	HOLD
4	20	80.03	100	93.97	7	593	20.03	Half Cover (1,7122)	ABSENT	767	HK33 ARMOR PIERCING	5.56	HOLD
5	20	78.01	100	78.99	9	577	19.85	Half Cover (1,7122)	0,02g 2L 150g/ml	734	HK33 ARMOR PIERCING	5.56	HOLD
6	40	157	200	192	8	602	20.2	Full Cover (3,8339)	ABSENT	951	BORA SNIPER	7,62x10	HOLD
7	30	112.13	150	127.82	4	573	19.78	Full Cover (3,8339)	0,03g 2L 150g/ml	813	BIXI	7,62x10	HOLD
8	20	74.82	100	89.18	6+10	473	19.62	Full Cover (3,8339)	0,02g 2L 150g/ml	637	BIXI	7,62x10	HOLD
9	40	156.63	200	184.37	5	588	19.67	Half Cover (1,7122)	0,04g 2L 150g/ml	929	BIXI	7.62	HOLD
10	20	75.86	100	91.14	3	600	20.18	Half Cover (1,7122)	0,02g 2L 150g/ml	767	BIXI	7.62	HOLD
11	35 (20cmx20cm)	544	700	667	1+2	2859	24.41	Full Cover (3,8339)	ABSENT	4070	MG2	12.7x99	PASS
12	30	109.05	150	115.95	ABSENT	ABSENT	ABSENT	Full Cover (3,8339)	0,03g 2L 150g/ml	225	MG2	12.7x99	HOLD
13	20	76.9	100	85.1	ABSENT	ABSENT	ABSENT	Half Cover (1,7122)	0,02g 2L 150g/ml	162	MG2	12.7x99	HOLD
14	60 (20cmx30cm)	1387	1800	1700	11+12+13	9263	53.66	3 Full Cover (11,5017)	0,36g 2L 150g/ml	12350	MG2	12.7x99	HOLD
15	40 (10cmx10cm)	149	200	200	14+15	875	31.81	Full Cover (3,8339)	0,04g 2L 150g/ml	1224	MG2	12.7x99	HOLD
16	40 (10cmx10cm)	150	200	215	16+17	872	31.84	Full Cover (3,8339)	0,04g 2L 150g/ml	1237	MG2	12.7x99	HOLD

Figure 20. Ballistic test results.

5. CONCLUSIONS

From this study of the armor materials compositions we can find the following conclusion, in this study we selected several types of weapons as show below, For Gun CEN BR2 with bullet type 9.19 mm, with type of weapon we applied three tests as explain in the following, in the first test armor made from polyethylene and polyester, after this test the resistance of the armor is failed, because the bullet passed the armor. Second test to improve armor properties, we made another composition of material with Gun CEN BR2, these materials are polyethylene, polyester and cobalt, after test the result it is successful to improve the armor resistance against bullet of the gun. We apply third test of the armor with the Gun CEN BR2 by added graphene to the composition in the second test, we can see the benefit of the graphene addition further to improve the resistance of the armor is decreasing the weight of the armor.

Figure 21. Pistol (9.19mm) result.

For HK33 Armor Piercing with bullet type 5.56 mm, we applied two tests with this gun in the first test armor materials are polyethylene, polyester, ceramic and cobalt, after test armor resistance against the bullet of the HK33 is successful. In the second test of the armor with HK33 weapon we added graphene to the same composition like in the first test, after test we can see the resistance of the armor is greater than the armor makes, without graphene.

Figure 22. Rifle (HK33 5.56mm) result.

For BORA SNIBER BR7 with bullet type 7.62*10 mm, armor materials used with this weapon are polyethylene, polyester, ceramic, and cobalt, after test armor resistance is successful against the bullet of this weapon. For BIXI with bullet type 7.62*10 mm, with this weapon we applied four tests of armor as explain in the following, in the first test the armor materials are polyethylene, polyester, ceramic, cobalt and graphene, after test the armor resistance against the bullet of BIXI weapon is successful. In the second test we used armor materials like as used in first test, but we changed the amount of materials, after test the armor resistance against the bullet is successful, the profit from the changed to decrease the amount of material leads to decrease the cost of armor make. Third test , in this test we used armor materials like the materials which are used in the first test, but here we increase the amount of polyethylene, polyester and graphene greater than used in test one, and in this test we used the amount of cobalt less than used in test one, after test the results of the armor resistance against the bullet of BIXI weapon is successful, the profit of the materials composition in this test is to increase the amount of the carbon in the armor which is leaded to increase the hardness of the materials. Fourth test, in this test we used materials of armor like that which are used in the test one, but in this test we decrease the amount of polyethylene, polyester, cobalt and graphene less than which are used in test one, after test the resistance of the armor against the bullet of BIXI is successful, the profit of this new composition of armor materials is to decrease the weight of armor which is leaded to decrease the cost make of armor.

Figure 23. Rifle (BIXI 7.62mm) result.

For MG2 with bullet type 12.7*99 mm, with this type of weapon we applied six tests as explain in the following, in the first test, materials armor used in this test are polyethylene, polyester, ceramic and cobalt without graphene, after test armor resistance against the bullet of MG2 weapon is failed. In the second test, materials armor used in this test are polyethylene, polyester, cobalt and graphene without ceramic after test the resistance of the armor against bullet of MG2 weapon is failed. In the third test, materials armor used in this test are polyethylene, polyester, cobalt and graphene without ceramic, in this test we used the amount of polyethylene, polyester and cobalt is less than which are used in test one and in this test we used graphene, after test the resistance of the armor against the bullet of MG2 is successful.

In the fourth test, materials armor used in this test are polyethylene, polyester, ceramic, cobalt and graphene, after tests armor resistance against the bullet of MG2 weapon is successful. In the fifth test, materials armor used in this are like that which are used in test fourth, but in this test we used the amount of materials are less than the amount of materials which is used in test fourth, after test the resistance of the armor against the bullet of MG2 is successful, the profit of this test is to decreases the weight of the armor and decrease the cost make of armor. Six test, in this test we applied the materials like that which are used in the fifth test, we applied this test to give us more certainly of the result.

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APPENDIX: EXTENDED TURKISH SUMMARY (GENİŞLETİŞMİŞ TÜRKÇE ÖZET)

TEZİN ADI: YENİ NESİL UHDPE MALZEMELERİNİN BALİSTİK PERFORMANSLARININ İNCELENMESİ

TEZİN AMACI VE ÖNEMİ

Yeni nesil nanokompozit teknolojik malzemelerin; inşaat, ambalaj, tekstil, otomotiv, havacılık, savunma, sağlık, tarım ve elektrik/elektronik gibi gelişmeye açık, Ar-Ge stratejilerinde öncelikle Ür-Ge ye daha sonrasında ise yüksek ekonomik getirili, katma değeri yüksek seri üretime uygun ürünler elde edilmeye çalışılmaktadır. Gelişen dünya politikaları ve bulunduğumuz coğrafi çevre etkisi nedeni ile, "Savunma Sanayii Plastikleri" ayrı bir taktiksel öneme sahip malzemeler olarak ön plana çıkmaktadır. Savunma sanayinde daha dayanıklı zırh teknolojisinde başarılı çalışmalar yapılmaktadır. Yine bu alanda ortaya çıkan kompozt zırhlar büyük bir önem meydana getirmektedir. Klasik tarz, çelikten yapılan yada betondan yapılan kalın ve ağırlığı fazla olan zırhların yerine artık zırhların ince ve hafif olmasına olanak sağlayan kompozit zırhlar üretilmektedir.

Klasik zırhlar kalın ve ağır olmalarının yanı sıra bir başka dev avantaja sahiptirler bu dezavantaj klasik zırhların esnek olmamasından dolayı kolay şekillenememelerinden kaynaklanmaktadır. Kolay şekil kazanamadıkları için kırılgan bir haldedirler ve zırh teknolojinde asıl olan durdurmanın yanı sıra sağlanması gereken bir diğer şeyde atılan mühimmatın enerjisinin zırh ile tamamen emilmesi ile zırha temas ettikten sonra başka bir yöne meyil almasına engel olmaktır. Yeni nesil kompozit zırhlar ile mühimmat tamamen durdurulmakta ve zırha temas ettikten sonra başka bir yöne meyil alması engellenmektedir.

Bu çalışmamızda kompozit malzemelerin önemli faktörlerinden olan hafiflik ve kalınlık dikkate alınarak daha dayanıklı ve daha dirençli olacak şekilde olabilecek en ince ve hafif hale getirilmeye çalışılmıştır. Bu istenilen sonuçları elde etmek için daha az maliyet ile kaliteli bileşenler hazırlanmıştır ve mükemmel sonuçlar elde edilecek dirençli bir tasarım elde edilmiştir.

Bu kompozit malzemelerin muadillerine nazaran daha az karmaşık modelleme ihtiyacından dolayı daha az bir maliyet ile modellemeleri yapılmıştır. Farklı değerlerde çok sayıda modelleme yapılarak testleri tamamlanmıştır. Burdan da görüleceği üzere daha hafif ve daha ince olmasından dolayı daha uygun maliyetler ile başarılı sonuçlar elde edilmiştir. Balistik koruma için uygulanan metotlar ve yöntemler test aşamalarında uygulanmış ve başarılı sonuçlar elde edilmiştir.

KAYNAK BİLDİRİŞLERİ

Kompozit Zırhın Tanımı

Kompozit zırh, metaller gibi klasik malzemelerin gelişen teknolojinin ihtiyaçları için yeterli olamamasından, daha iyi özelliklere sahip olan kompozit malzemeler üretilmeye başlanmıştır. Bu konuda hızlı bir gelişme sürecine girilmiştir. Klasik malzemelere nazaran kompozit malzemelerin en öne çıkan özellikleri hafiflik ve sağlamlıklarıdır. Yapılan araştırmalar ve geliştirmeler neticesinde, bu malzemelerin çekme, darbe dayanımlarının artırılması; kimyasal direnç, yorulma ve elektriksel özelliklerinin iyileştirilmesi mümkün olmuş ve kompozit malzemeler yaygın şekilde deniz taşıtları, havacılık, otomotiv, inşaat, makine, askeri ve uzay teknolojisi gibi alanlarda kullanılmaya başlanmıştır.

Kompozit Zırhın Önemi ve Özellikleri

Kompozit malzemeler genelde bir veya birkaç çeşit elyaf, çeşitli rijit parçacıkların reçinelerle veya metal/seramik matrislerle değişik şekilde süreçlere bırakıması ile elde edilirler. Bu amaçla kullanılan elyaflarsa cam karbon , seramik, aramid ve karışık elyaf olabilmektedir. Elyaf yerine bazen elyaftan üretilmiş keçe veya dokuma da kullanılmaktadır. Böylece dayanım dahada artmıştır ve üretimde de pratiklik sağlanmıştır. Kompozit malzemelerin başlıça avantajları; fiziksel özelliklerinin ayarlanabilmeleri, hafiflikleri, ağırlıklarına nazaran yüksek mukavemetleri, uzun yorulma ömürleri, kimyasal dayanımları ve karmaşık şekillerin kolay imalatlarıdır. Reçine maddesi dışında, kompozit malzemelerin yapımında metal matrisler de kullanılabilmektedir. Alüminyum-grafit, magnezyum-grafit gibi metal matrisler örnek olarak verilebilirler. Kompozit malzemelerin, yumuşak çelikten daha dayanıklı, titanyumdan daha sert ve alüminyumdan daha hafifleri oluşturulmuş olmasına rağmen, bu alandaki araştırmalar hala devam etmektedir ve bu tür malzemelerin gelecekte daha yaygın olarak kullanılacak çok önemli mühendisliki malzemeler olacakları tahmin edilmektedir.

MATERYAL VE YÖNTEM

Materyal

Bu projede UDPE (Ultra Yoğunluklu Poli Etilen) özel kumaş kullanılmıştır. Sağlamlığını arttırmada ve rijit bir yapı kazandırmada tercih edilen reçine polyester kullanılmıştır. Esneklik ve ısıya dayanım gibi diğer özellikler içinde belirli oranlarda kobalt ve grafen kullanılmıştır.

Kimyasal Reaksiyon

Polyester farklı bir kütle yüzdesine sahip (30%, 50% ve70%) pembe bir renge sahiptir. Polyester hassas bir terazide tartılıp manyetik bir karıştırıcıda test tüpüne eklenecektir. Tepkimeyi başlatmak için içerisine belli olaranlarda (0.8%, 1% ve 2%) kobalt ve katalist eklenir ve kimyasal tepkime aktif hale gelmiştir artık ultra yoğunluklu poli etilen kumaş üzerine uygulacak durumdadır.

Polyesterin Kumaşa Uygulanması

Kimyasal işlem tamamlandıktan sonra çözelti uygulamalarda kullanılmaya hazır hale gelecektir. Uygulamayı fırça ile sürerek yapmalıyız bunun için sıvı bir faz olarak görünsede katıya yakın viskoz bir ürün olduğundan bu sıvı fazı sürülmeye hazır bir hale getirdikten sonra sürerek uygulayabiliriz. Uygulama için kumaş üzerine tam ve eşit bir şekilde dağıtılması için fırça kullanılmaladır boya yapıyormuş gibi özenle sürülmelidir. Kumaş kaplandıktan sonra oda sıcaklığında sertleşmeye bırakılır ilk yapım aşamasında oda sıcaklığının üzerinde olacaktır lakin oda sıkcaklığında kurumada kaldığı için sorun yaşanmayacaktır.

BULGULAR

Fırça ile sürerek kapalama işlemi bittikten sonra ve sertleşme tamamlandıktan sonra artık zırhımızın farklı mühimmatlara karşı dayanımını ölçmek için uygun bir atış sahasına giderek her türlü sağlık ve yaşam önlemlerini alarak test edebilir hale gelmiştir. Atış denemelerinde etkisi az olan mühimmattan etkisi fazla olan mühimmata doğru bir test işlemi uygulanmıştır. Başlangıç olarak tabanca mühimmatı olan 9.19mm mühimmat kullanılmış ve başarılı olunmuştur. İkinci aşamada 5.56mm HK33 mühimmatı kullanılmış ve başarılı olunmuştur. Üçüncü aşamada 7.62mm AK47 mühimmatı kullanılmış ve başarılı olunmuştur. Dördüncü aşamada 7.62mm BORA SNIPER mühimmatı kullanımış ve başarılı olunmuştur. Beşinci aşamada 7.62mm BIXI mühimmatı kullanımış ve başarılı olunmuştur. Altıncı aşamada 12.7mm MG2 mühimmatı kullanımış ve başarılı olunmuştur. Yedinci aşamada DOCKA mühimmatı kullanımış ve başarılı olunmuştur ve sekizinci aşamada RPG mühimmatı kullanımış ve başarılı olunmuştur.

SONUÇ

Gelişen dünya siyasetine ve coğrafi çevresel etkisine sahip olan "Savunma Sanayii Plastikleri", ayrı bir taktik tasarıma sahip bir malzeme olarak ön plana çıkıyor. Savunma teknolojilerindeki düşman unsurlarına karşı savunmada büyük ilerlemeler kat edilmiş ve bu ilerlemeler neticesinde yapılan çalışmlarımızda kullandığımız kompozit malzemeye sayesinde muadillerinden çok daha başarılı sonuçlar elde edilmiş ve mühimmat aralığı çok geniş bir yelpaze de başarılı olunmuştur.

Çalışmanın bir sonraki kısmı doktora sırasında tartışılacak ve devam edecektir.

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