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Investigation of Ballistic Behavior of Agricultural Waste Doped Hybrid Composite Plates in Vacuum Infusion Method

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Abstract: The vacuum infusion method is used in the production of ballistic composite materials, in the repair of aircraft parts and in the production of layered hybrid composite materials. In this study, production of hybrid composite materials including apricot kernel shell powder, hazelnut shell powder, walnut shell powder and graphene nanopowder added layer were made by vacuum infusion method. Layered hybrid composite samples with pure graphene nanopowder added and different shell powder added were produced. Then the produced hybrid composite samples were subjected to ballistic experiments. Due to the security, only the photographs of the ballistic test results were allowed to be shared.

Keywords: Apricot kernel shell powder, hazelnut shell powder walnut shell powder, graphene, composite material

Tarımsal Atık Katkılı Hibrit Kompozit Plakaların Balistik Davranışlarının Vakum İnfüzyon Yönteminde Araştırılması

Öz: Vakum infüzyon yöntemi, balistik kompozit malzemelerin üretiminde, uçak parçalarının onarımında ve katmanlı hibrit kompozit malzemelerin üretiminde kullanılır. Bu çalışmada kayısı çekirdeği kabuğu tozu, fındık kabuğu tozu, ceviz kabuğu tozu ve grafen nanotozu katkılı tabaka içeren hibrit kompozit malzemelerin üretimi vakum infüzyon yöntemi ile yapılmıştır. Saf grafen nanopowder eklenmiş ve farklı kabuk tozu eklenmiş katmanlı hibrit kompozit numuneler üretildi. Daha sonra üretilen hibrit kompozit numuneler balistik deneylere tabi tutulmuştur. Güvenlik nedeniyle, yalnızca balistik test sonuçlarının fotoğraflarının paylaşılmasına izin verilmiştir.

Anahtar kelimeler: Kayısı çekirdeği kabuğu tozu, fındık kabuğu tozu, ceviz kabuğu tozu, grafen, kompozit malzeme.

1. Introduction

People have felt the need to always be self-preserving throughout the history due to their survival instinct. For this reason, mankind has acted with the instinct of protection both in daily life and in case of war. With the expansion of armament in our world, protective armor are used for defense purposes. After the 13th century, mankind defended itself with swords and protected itself against the dangers by steel armor designed to protect itself [1].

The rapidly developing weapon technology has gained a new dimension and research fields after the discovery of gunpowder and firearms. With the developing weapon technology, the weight of weapons has started to decrease. With the increasing impact and range of the weapon; Lightness,

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high strength, high bullet absorption properties are needed in building, vehicle and personnel armor [2]. Ballistic protective clothing protects people and equipment against all kinds of explosive, penetrating and cutting hazards [3].

Composite materials are materials formed by combining at least two or more materials in a macro scale. The aim is to improve the weaknesses of the materials used [4]. Macro-scale bonding allows for materials with superior properties.

Thanks to the rapid developments in composite material technology, the applications of composite materials in industry and technology are being used in increasing rates day by day. One of the most important applications of composite materials in these areas is the damage repair of pipes due to internal pressure and varying temperature rates. In the repair of damaged galvanized steel pipes, three different types of patch materials, composite, aluminum and steel, were selected and the effect of these types on one type of adhesive was investigated [5,6].

The discontinuities of polymer matrix composite products obtained by vacuum infusion method were determined and samples were subjected to tensile test. The mechanical test data of the tensile test and non-destructive testing were compared [7]. The most commonly used composite material components in vacuum infusion method are; glass fiber- polyester, carbon fiber- epoxy and aramid fiber- epoxy combinations [8].

Layered composite materials are used in yacht and boat production methods. Vacuum infusion method composite materials were obtained from the manufacturer of the yacht company and produced in the laboratory of the hull body laminate sandwich sandwich plates in accordance with ASTM standards 3-point bending tests were performed. The force-displacement plots were obtained at different support distances and sample widths of the sandwich composite samples, the maximum strength and displacement values, the resilience in the elastic region and the maximum force values were found [9].

With the production of fibrous structures with high strength properties, there has been considerable progress in the production of high-strength fabric armor systems. There are three types of impacts to which a laminated composite material will be exposed. The first pulse type and the low energy pulse is called a low speed pulse [10]. The high-energy pulse is also called high-speed pulse energy. The third type of impact is the high-speed pulse type, which has higher energy compared to the other two specie [11]. Damage mechanisms occurring in stratified composite materials during ballistic impact; delanimation, fiber breakage and matrix breakage [12, 13]. These types of damage are shown in Figure 1.1, 1.2 and 1.3.

(1) (2) (3)

Figure 1. The types of ballistic impact (1) Delanimation (2) Fiber breakage (3) Matrix breakage [13]

Damage to stratified composite materials exposed to impact at ballistic speed depends on the modulus of elasticity of the target, strength properties, layer properties, shape and mass of the object, environmental conditions [14, 15, 16]. Delamination is defined as the separation of any layer forming the laminated composite material. Separation occurs in the matrix material in the region called the interlayer surface between each layer.

In the field of composite material production, the resin infusion is a process in which cavities in an evacuated porous material stack are filled with liquid resin When the resin solidifies, the solid resin matrix forms a rigid composite by allowing the materials to be joined together. The reinforcement may be any porous material compatible with the resin Typical materials are inorganic fibers (the most common of glass fiber), organic fibers such as flax or closed cell foams, combinations of fibers with other materials such as balsa and honeycomb. Resins are generally thermoset types, but thermoplastic resins can also be used for infusion [17]. The Vacuum Infusion Process (VIP) uses a vacuum to flush the resin into the laminate. The dry material is then sealed using a vacuum bag or a counter-mold. A high vacuum pump is used to remove all air in the cavity and combine the fiber and core materials. Under vacuum, the resin is introduced into the mold cavity to wet the fabric fibers and core [18].

The vacuum infusion process is very simple as a concept; however, it requires detailed planning and processing design so that the pieces can be brewed at a reasonable time without any dry spot. The infusion rate depends on the viscosity of the resin, the distance the resin needs to flow, the permeability of the medium and the amount of vacuum. Therefore, the choice of material, the flow medium, the flow pattern of the resin, and the location of the vacuum connection points are critical in making good parts. The advantage of the vacuum infusion process is to form a laminate with a very high fiber content (up to 70% by weight), thereby creating a very high strength and a hard piece of minimal weight [19,20].

In general, the vacuum infusion process in Figure 2 consists of 4 main elements. These elements are resin tank, prepared vacuum infusion mold, resin collector (crystal collector) and vacuum pump. In general, the vacuum infusion die, the vacuum holes or the channels are formed around the perimeter of the part and the resin is in the center of the insert. The goal is to ensure that the resin is wetted as quickly as possible without dry areas [20]. Additional resin inlet lines can be added for complex parts.

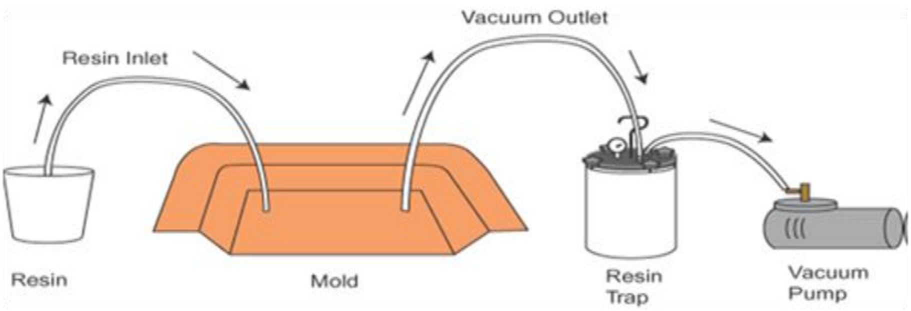

Figure 2. The vacuum infusion process main elements [20]

2. Experimental Methods

The samples with three different contents for the ballistic experiments used in this study were produced in the vacuum mechanics laboratory in Inonu University Faculty of Engineering Materials Mechanics Laboratory. The production of layered composite materials was carried out by vacuum infusion method.

Apricot seed peel powders were obtained by using grinders and sieves from TERSUN. The micron range of ground apricot kernel powder is 0-250, 250-400, 425-600 and 600-825 microns. Hazelnut husk powder and walnut husk powder were ground with the help of ball drum in Inonu University Malatya Vocational School Construction Department Laboratory. The grinding process was in the range of 5000-7500 cycles on average.

The grinding time of the shells was completed in an average of 3 hours. The crust powders obtained after grinding process were sieved by sieves in the sieving machine. The screening process in the sieving device was completed in 1 hour. At the end of this process, crust powders were obtained at 0-75, 75-300, 300-425, 425- 625 and 625-825 μm intervals, respectively. The photographs of the ball drum grinder and sieving machine used in the grinding and sieving process are shown in Figure 3.1 and 3.2.

(1) (2)

Figure 3. (1) Grinding Machine, (2) sieving machine.

Epoxy resin and hardener are used in the production of stratified hybrid composite materials. The reinforcement materials used in the three kinds of samples are shown in Table 1. The amount of reinforcement materials used for the graphene nanopowder (GN) doped sample produced, the amount of reinforcement materials of the apricot kernel shell powder, hazelnut shell powder and graphene nanopowder added (GNFK) and the apricot kernel shell powder, walnut shell powder, nutshell powder and graphene nanopowder the amount of reinforcing materials used for the sample with GNFKC added is given in Table 2. The curing process was 8 hours at 44 de and 4 hours at 88.

Table 1. Reinforcement materials used in the experiment

Order	Material Name	Type	Mass
1	Carbon Fiber Ballistic Purpose Fabric	12k-twill	420 gr/m^2
2	Carbon Fiber Fabric Stitched	0 °	300 gr/m^2
3	Carbon Fiber Fabric	12k-twill	420 gr/m^2
4	Aramid Fabric	Plain	200 gr/m^2

Application of shell powders on the layers in GN, GNFK and GNFKC samples is given in Tables 3, 4 and 5. Between the specified layers of the GN sample, the graphene nanopowder was laid out evenly.

In the first step of vacuum infusion method, fabrics were cut with the help of chargeable fiber scissors. The cut fabrics were weighed by calibrating the precision balance. As the first step in the vacuum infusion process, the surface of the machine has been completely cleaned and the surface of the machine has been cleared of dust, dirt and small particulate residues. The numbering of all same production by vacuum infusion process stage images is given in Figure 4, starting from 1 to 8, respectively.

Table 2. Amount of reinforcement materials used in GN, GNFK and GNFKC samples

Materials Name	**GN**		**GNFK**		**GNFKC**	
Used Fiber Type	**Number of Sheets**	**Material Mass (gr)**	**Number of Sheets**	**Material Mass (gr)**	**Number of Sheets**	**Material Mass (gr)**
Carbon Fiber Ballistic Purpose Fabric	4	144.56	3	134.63	6	348.63
Aramid Fiber Fabric	2	47.28	2	52.93	2	97.47
Carbon Fiber Fabric Stitched 300gr/m^2	3	68.15	2	67.08	3	139.62
Carbon Fiber Fabric	2	48.15	2	86.00	3	143.00
Graphene Nanopowder	7	31.63	4	34.97	16	74.75
Amount of Apricot Kernel Shell Powder	-	-	6	33.19	16	87.87
Amount of Hazelnut Shell Powder	-	-	3	20	16	35
Amount of Walnut Shell Powder	-	-	-	-	16	39.94

Table 3. Layers of graphene nanopowder in GN sample

Sheets	**Layer Type**	**Graphene**
1-2	Carbon Fiber Ballistic P. F.	%100
2-3	Carbon Fiber Ballistic P. F.	%100
3-4	Carbon Fiber Ballistic P. F.	%100
4-5	Carbon Fiber Ballistic P. F.	%100
5-6	Aramid Fiber Fabric	-
6-7	Carbon Fiber Fabric Stitched 300gr/m^2	%100
7-8	Carbon Fiber Fabric Stitched 300 gr/m^2	-
8-9	Carbon Fiber Fabric Stitched 300gr/m^2	%100
9-10	Carbon Fiber Fabric	%100

P.F: Purpose Fabric

Table 4. Layers of shell dust and graphene nanopowder in GNFK sample

Sheets	**Layer Type**	**Graphene**	**Apricot Kernel Shell**	**Hazelnut Shell**
1-2	Carbon Fiber Ballistic P.F.	%30	%40	%20
2-3	Carbon Fiber Ballistic P.F.	%40	%30	%20
3-4	Carbon Fiber Ballistic P.F.	%40	%50	%10
4-5	Aramid Fiber Fabric	-	-	-
5-6	Aramid Fiber Fabric	-	%100	-
6-7	Carbon Fiber Fabric Stitched 300 gr/m2	%40	%60	-
7-8	Carbon Fiber Fabric Stitched 300gr/m2	-	%100	-
8-9	Carbon Fiber Fabric	-	-	-

P.F: Purpose Fabric

Table 5. Layers of shell dust and graphene nanopowder in GNFKC sample

Sheets	Layer Type	Graphene	Apricot Kernel Shell	Hazelnut Shell	Walnut Shell
1-2	Carbon Fiber Ballistic P. F	%30	%40	%20	%10
1-2	Carbon Fiber Ballistic P. F	%50	%30	%20	%10
1-2	Carbon Fiber Ballistic P. F	%50	%30	%10	%10
2-3	Carbon Fiber Ballistic P. F	%30	%40	%20	%10
2-3	Carbon Fiber Ballistic P. F	%55	%40	%20	%10
2-3	Carbon Fiber Ballistic P. F	%50	%30	%10	%10
3-4	Carbon Fiber Ballistic P. F	%5	%90	%2.5	%2.5
4-5	Carbon Fiber Ballistic P.F.	%30	%50	%10	%10
4-5	Carbon Fiber Ballistic P. F	%30	%50	%10	%10
5-6	Carbon Fiber Ballistic P. F	%50	%40	%5	%5
5-6	Carbon Fiber Ballistic P. F	%50	%44	%3	%3
6-7	Carbon Fiber Ballistic P. F.	%20	%60	%10	%10
7-8	Aramid Fiber Fabric	%50	%40	%5	%5
8-9	Aramid Fiber Fabric	-	-	-	-
9-10	Carbon Fiber Fabric Stitched 300 gr/m^2	-	-	-	-
10-11	Carbon Fiber Fabric Stitched 300gr/m^2	%20	%60	%10	%10
11-12	Carbon Fiber Fabric	-	-	-	-
12-13	Carbon Fiber Fabric	%22	%74	%2	%2
13-14	Carbon Fiber Fabric	%30	%66	%2	%2

P.F: Purpose Fabric

In the second step, the mold release film to the area where the fiber fabric fibers will be laid is cut in accordance with the sample sizes to be produced as seen in Figure 4.1 and 4.2. The mold release nozzle is fixed on the vacuum infusion bench with the help of adhesive tape. Then, the fibers were placed on the separating vacuum nylon one by one and the powder layers were laid between the fiber layers (Figure 4.3 and 4.4). In the third step, the layered fiber layers are covered with peel ply fabric, which is prepared according to the mold dimensions. In the fourth step, the peel ply fabric was laid on the fibers and fixed, the flow mesh was laid on the peel ply fabric and the mesh were centered. In the fifth step, the vacuum hoses are fixed to the ends of the T-connections placed in the spiral hose after the separator film has been laid.

The separator film was then taped with sealing tape. After fixing the spiral hoses, the top reagent film was glued onto the sealing tapes and the mold preparation process was completed (Figure 4.5). Then the vacuum was processed and the epoxy-resin hardener mixture was impregnated into the mold (Figure 4.6), The curing process applied to the sample is shown in Figure 4.7 and the image of the produced samples is given in Figure 4.8.

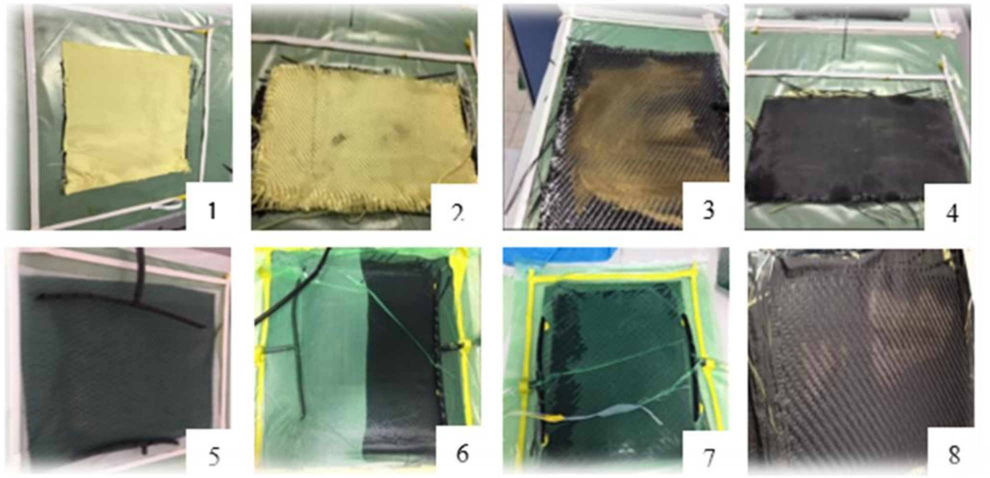

Figure 4 . (1) spreading of mold release film, (2) laying of fibers,(3) spreading of shell powders, (4) completion of laying process ,(5) fixing the elements of the mold, (6), Impregnation of the mixture, (7) curing process, (8) procuded sample

Vacuum infusion method Total mass of materials produced by vacuum infusion method is weighed with the help of scales. The mass, volume, specific density and thickness of the data of the samples are given in Tables 6, 7 and 8. The symbols h in Tables 6,7 and 8 show the thickness of GN, GNFK and GNFKC samples.

Table 6. Data for GN sample

Total Mass (gr)	**Fiber Mass (gr)**	**Total Specific Gravity (gr/cm^3)**	**Fiber Specific Gravity (gr/cm^3)**	**Matrix Mass (gr)**
970	308.12	1.141	4.736	630.25
Matrix Specific Gravity (gr/cm^3)	**Graphene Mass (gr)**	**Graphene Specific Gravity (gr/cm^3)**	**H (mm)**	**Mass Matrix Ratio**
1.108	31.63	0.10	9.50	0.649
Mass Fiber Ratio	**Total Volume (cm^3)**	**Fiber Volume (cm^3)**	**Matrix Volume (cm^3)**	**Graphene Volume (cm^3)**
0.351	950	65.052	568.818	316.300

Table 7. Data for GNFK sample

Fiber Mass (gr)	**Total Specific Gravity (gr/cm³)**	**Fiber Specific Gravity (gr/cm³)**	**Matrix Mass (gr)**	**Matrix Specific Gravity (gr/cm³)**	**Graphene Mass (gr)**	**Graphene Specific Gravity (gr/cm³)**
340.63	0.956	3.487	618.181	1.108	34.972	0.10
Mass Matrix Ratio	**Mass Fiber Ratio**	**Apricot Kernel Shell Specific Gravity(gr/cm³)**	**Apricot Kernel Shell Powder Mass(gr)**	**Hazelnut Shell Powder Mass(gr)**	**Hazelnut Shell Specific Gravity (gr/cm³)**	**Total Volume (cm³)**
0.611	0.389	1.336	33.189	20.00	0.540	1058.2
Fiber Volume (cm³)	**Matrix Volume (cm³)**	**Graphene Volume (cm³)**	**Apricot Kernel Shell Powder Volume(cm³)**	**Hazelnut Shell Powder Volume(cm³)**		
97.676	557.925	340.720	24.842	37.037		

Table 8. Data for GNFKC sample

Sample Name: GNFKC					
Total Mass (gr)	**Fiber Mass (gr)**	**Total Specific Gravity (gr/cm³)**	**Fiber Specific Gravity (gr/cm³)**	**Matrix Mass (gr)**	**Matrix Specific Gravity (gr/cm³)**
1678.800	728.090	0.956	2.273	713.560	1.108
Graphene Mass (gr)	**Graphene Specific Gravity (gr/cm³)**	**h (mm)**	**Mass Matrix Ratio**	**Mass Fiber Ratio**	**Apricot Kernel Shell Specific Gravity (gr/cm³)**
74.750	0.10	9.94	0.425	0.575	1.336
Apricot Kernel Shell Mass (gr)	**Hazelnut Shell Mass(gr)**	**Hazelnut Shell Specific Gravity (gr/cm³)**	**Walnut Shell Mass (gr)**	**Walnut Shell Specific Gravity (gr/cm³)**	**Total Volume (cm³)**
87.792	39.940	0.54	35.00	0.48	1924.384
Fiber Volume (cm³)	**Matrix Volume (cm³)**	**Graphene Volume (cm³)**	**Apricot Kernel Shell Volume(cm³)**	**Hazelnut Shell Volume(cm³)**	**Walnut Shell Volume (cm³)**
320.286	644.007	747.500	65.712	73.962	72.917

Ballistic tests were performed with 9x19 mm projectiles from 10 m depending on NIJ Level II-A standards. In this context, the bullet mass was measured at 8.1 g on the jeweler's scale. The resultant photographs of the shot samples are shown regionally. The firing was made with the Sarsılmaz Branded B6. The image representing the experimental setup is shown in Figure 5.

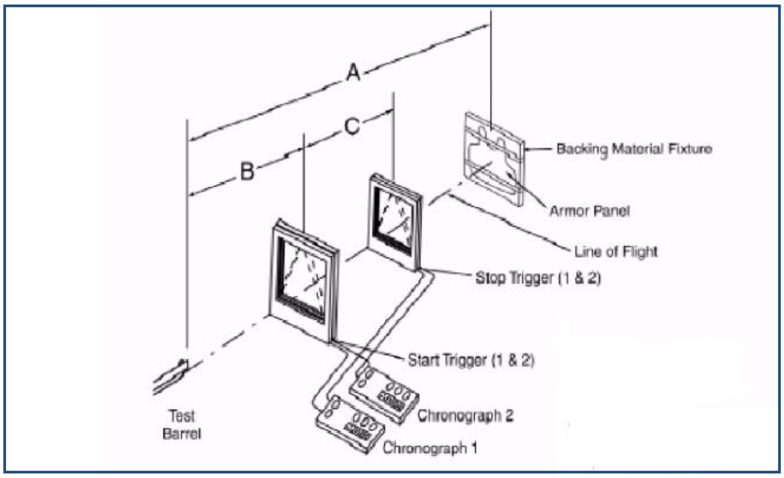

Figure 5. Ballistic experiment setup

The distance A in the figure is 10 m long. The distance B is the distance between the shotgun and the first chronograph. The distance B is 3 m. The distance between the two chronographs is 4 m. This distance is expressed in C. The images of 9 mm FMJ projectiles used during ballistic experiments are shown in Figure 6.1 and the horizontal image of the projectiles is shown in Figure 6.2.

Figure 6. (1) Ballistic experiment of a 9 mm FMJ bullet, (2) the horizontal image of the projectiles

3. Results and Discussion

As a result of the ballistic test results of the GN sample, the hybrid composite plate belonging to the shots 1, 2, 3 is deposited on the back side of the sample. The deposition images of the shots 1 and 2 on the front face of the plate composite are shown in Figure 7.2, the image of shot 3 is shown in Figure 7.3 and the amount of deposition is measured by means of a caliper in Figure 7.4.

The ballistic limit of the graphene nanopowder (GN) sample was found to be between 350 m / s and 400 m / sec. The ballistic tests were successful by keeping all the shots in the plate. The resulting average precipitation value is 6.187 mm. This sample provides protection according to the NIJ Level II-A standard. The ballistic test results of the GN sample are given in Table 9.

The highest firing rate, number 3 and the number of collapsed shots at the highest shot was hit by the bullet core. It shows that it has absorbing properties and standards. The reason for the high number of dents in shot 2 is that the damage caused by the bullet in the plate is higher than in the other shots.

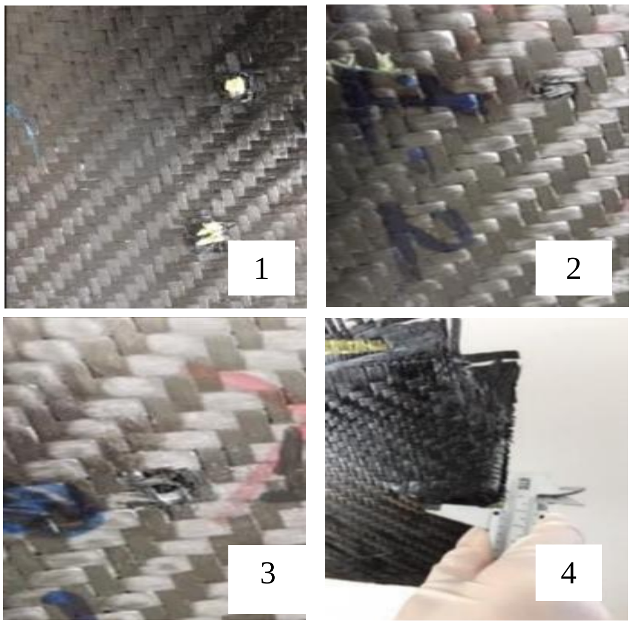

Figure 7 (1) Three shots is deposited on the back side of the sample, (2) shots 1 and 2 on the front face of sample , (3) shot 3 of sample (4) deposition quantities measured

The perforation did not occur in the shots given to the GNFK sample given in Table 10 and this sample was successful. Damage to the carbon fiber fabric running as the backing plate has been the most severe. The ballistic limit of GNFK was found to be between 360 m / s and 440 m / sec.

Table 9. Ballistic test data of GN sample

Shooting Number	Shooting Speed (m/sn)	Kinetic Energy (J)	Multiplication Speed (m/sn)	Absorbed Energy (J)	Depression Amount (mm)	Evaluation
1	358.688	521.061	252.850	258.929	6.000	No Puncture
2	382.580	592.788	260.560	274.960	6.312	No Puncture
3	398.878	644.369	264.450	283.250	6.250	No Puncture
Average	**380.048**	**586.072**	**259.286**	**272.059**	**6.187**	

When the shots are taken into consideration, the mean collapse value is 5.816 mm, corresponding to an average of 404.054 m / sec projectile velocity. 5 shots of GNFK samples are caused by the fact that the shell powders do not have a homogenous distribution and the number of material layers is different. Photographs of fire tests performed on hybrid epoxy resin matrix GNFK sample ballistic test result of shots 1 and 2 in Figure 8.1, shots 3 and 4 Figure 8.2, and shot 5 Figure 8.3.

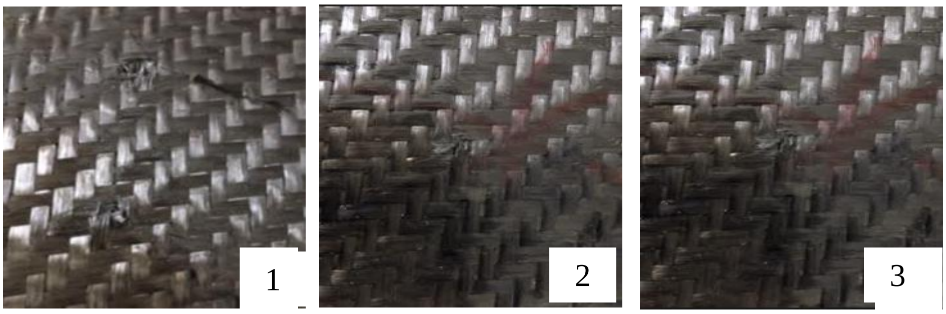

Figure 8. Ballistic test of results GNFKC sample 1) Shots 1 and 2, (2) shots 3 and 4, (3) shot 5

Table 10. Ballistic test data of GNFK sample

Shooting Number	Shooting Speed (m/sn)	Kinetic Energy (J)	Multiplication Speed (m/sn)	Absorbed Energy (J)	Depression Amount (mm)	Evaluation
1	392.500	623.920	268.478	291.925	6.220	No Puncture
2	424.126	728.525	270.455	296.240	5.433	No Puncture
3	375.789	571.930	256.889	267.267	5.880	No Puncture
4	389.000	612.850	287.588	334.892	6.125	No Puncture
5	438.859	780.010	298.988	362.044	5.422	No Puncture
Average	**404.054**	**663.447**	**276.479**	**325.154**	**5.816**	

Graphene nanopowder, hazelnut shell powder, walnut shell powder and apricot kernel shell powder were applied up to 10% of the weight of the fabric fiber in the sample. Photographs of fire tests performed on a 30-layer hybrid epoxy resin matrix GNFKC sample ballistic test result of shots 1 and 2 in Figure 9.1, shots 3,4,5 and 6 Figure 9.2, and shot 7 Figure 9.3.

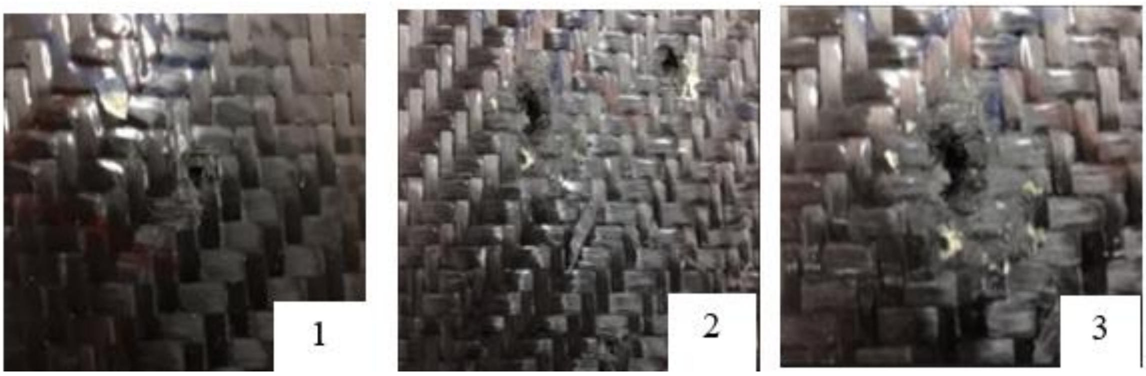

Figure 9. Ballistics test result of GNFKC sample (1) Shots 1and 2, (2) shots 3,4,5 and 6, (3) shot 7

The values of the ballistic test of the GNFKC sample are given in Table 11. At 7 shots, the speed of the shells is between 358 m / s and 440 m / s. None of these shots resulted in perforation. Therefore, the sample was successful. Separations occurred in support panels after firing. According to the results obtained from these shots, the highest sample weight is obtained from the GNFKC sample. In addition, the sample with the highest energy capacity and efficiency is the sample in this experiment.

Table 11 . Crash velocity data for GNFKC sample

Shooting Number	Shooting Speed (m/sn)	Kinetic Energy (J)	Multiplication Speed (m/sn)	Absorbed Energy (J)	Depression Amount (mm)	Evaluation
1	358.789	521.354	248.756	250.612	5.259	No Puncture
2	382.899	593.777	252.488	258.188	6.312	No Puncture
3	417.589	706.241	288.889	338.000	6.100	No Puncture
4	438.000	776.968	292.588	346.711	5.500	No Puncture
5	422.859	780.010	290.977	341.255	5.978	No Puncture
6	438.770	724.179	294.455	351.150	3.100	No Puncture
7	412.340	688.898	285.787	330.780	2.258	No Puncture
Average	**410.178**	**595.918**	**276.479**	**325.154**	**4.691**	

This sample provides protection according to the NIJ Level II-A standard. It is very important in terms of the energy efficiency that GNFKC sample absorbs when it looks at the sedimentation rate. It is seen that the materials produced with agricultural wastes can also be applied to the new generation of composite armor.

4. Conclusion

In the first part of the study, 3 layered hybrid composite plates were produced. Subsequently, these plates were subjected to NIJ standards by measuring the projectile velocities at a distance of 10 m and using 9 mm FMJ bullets and the results were examined. It is the GNFKC sample which is the most efficient in the analysis of the sedimentation of GN and GNFKC samples which can provide protection according to NIJ-0101.06 as a result of the ballistic tests. This is because the GNFKC sample is the most efficient sample with the highest test speeds and the ability to absorb the best energy. The results of the ballistic experiments showed that the homogeneous distribution of shell powders could not be achieved in the GNFK sample. This sample has also been able to absorb 5 of 5 bullets. When looking at the GN sample, it is a very efficient sample because it absorbs all shots in the projectile shots. The GN sample. The energy absorption effect is the most successful sample per unit weight.

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