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**Research Paper / Makale**

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**Simulation of Behavior of Carbon/Epoxy and Glass/Epoxy Composites Under the Drop Weight Impact Event**

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**Abstract:** Mechanical behaviors of materials are determined by experimental tests. In cases where the tests cannot be performed or a small number of samples can be tested, performing the numerical analysis is widely used for quick and reliable designs. This is particularly important for composite materials that are costly to design and manufacture but are widely used in many industries. Drop weight impact is a widely used test method to investigate the behavior of materials under the impact loads. Particularly in the areas where thin structures are frequently used, the behavior of materials under impact load is important. In this study, the behaviors of Carbon/Epoxy and Glass/Epoxy composite plates under the drop weight impact load was simulated. Composite materials have been used to have symmetrical fiber orientations. The effects of different configurations of Carbon/Epoxy and Glass/Epoxy composite plates are considered. Also, the thickness of the plate was increased by increasing the number of layers of the composite material and the effect of thickness increase on impact load was investigated. As a result, it is seen that the Carbon/Epoxy composite plate has a higher impact resistance than the Glass/Epoxy composite plate. The deformation of the Glass/Epoxy composite plate is higher than the Carbon/Epoxy composite plate. The maximum impact force increases with thickness increase for both materials.

**Keywords:** Composite materials, drop weight, impact.

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**Karbon/Epoksi ve Cam/Epoksi Kompozitlerin Düşen Ağırlık Darbe Testi Altındaki Davranışlarının Simüle Edilmesi**

**Özet:** Malzemelerin mekanik özellikleri deneysel testlerle belirlenir. Deneysel testlerin yapılamadığı veya az sayıda numunenin test edilebildiği durumlarda, sayısal analizlerin yapılması hızlı ve güvenilir tasarımlar için yaygın olarak kullanılır. Bu, tasarımı ve üretimi maliyetli olan ancak birçok endüstride yaygın olarak kullanılan kompozit malzemeler için özellikle önemlidir. Düşen ağırlık darbe testi, malzemelerin darbe yükleri altındaki davranışlarını araştırmak için yaygın olarak kullanılan bir test yöntemidir. Özellikle ince yapıların sıklıkla kullanıldığı alanlarda, malzemelerin darbe yükü altındaki davranışları önem arz etmektedir. Bu çalışmada, Karbon/Epoksi ve Cam/Epoksi kompozit plakaların düşen ağırlık darbe yükü altındaki davranışları simüle edilmiştir. Kompozit malzemeler simetrik fiber yönelimlerinde kullanılmıştır. Karbon/Epoksi ve Cam/Epoksi kompozit plakaların farklı konfigürasyonlarının etkileri dikkate alınmıştır. Ayrıca, kompozit malzemenin katman sayısı artırılarak plakanın kalınlığı artırılmış ve kalınlık artışının darbe yükü üzerindeki etkisi araştırılmıştır. Sonuç olarak, Karbon / Epoksi kompozit plakaların Cam/Epoksi kompozit plakaya göre daha yüksek darbe direncine sahip olduğu görülmektedir. Cam/Epoksi kompozit plakaların deformasyonu, Karbon/Epoksi kompozit plakaya göre daha yüksektir. Her iki malzeme için kalınlık artışı ile birlikte maksimum darbe kuvveti artmaktadır.

**Anahtar kelimeler:** Kompozit malzemeler, düşen ağırlık, darbe.

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## 1. Introduction

Materials have different behavior under the various loading conditions such as tension, compression, bending, twisting, buckling, and impact. Especially, impact resistance of materials important for the structures that used in the thin forms. Composite materials are today's material chose for the industries that need high specific strength and modulus. Drop weight impact is a widely used test method to investigate the behavior of materials under the impact loads. In cases where the test cannot be performed or a small number of samples can be tested, performing the numerical analysis is widely used for quick and reliable designs. This is particularly important for composite materials that are costly to design and manufacture but are widely used in many industries.

Drop weight impact resistances of different materials have been researched by many researchers. Villavicencio and Guedes Soares [1] investigated drop weight impact characteristics of plates experimentally. From this study, it was seen that the plastic behavior of the samples is directly related to the restraint at the supports. Santiago et al. [2] investigated the effects of local impact loads on the fiber-metal laminates (FML) produced with the combinations of aluminum alloys and polypropylene. Rawat et al. [3] studied failure characteristics of laminated composite plates using impactors having various shapes (hemispherical, spherical, oval shape, flat) under the impact loadings. The damage resistance of Steel and aluminum plates to a drop-weight impact event is researched numerically by Yeter and Doğru [4]. It was concluded that the damage resistance of the structural steel plate to a drop-weight impact event better than the aluminum plate used in this study. Yeter [5] investigated damage resistance of Armox 500T and Aluminum 7075-T6 plates subjected to drop-weight and ballistic impact loads. It was seen that the maximum impact loads of the Armox-500T target is higher than the Al7075-T6, and the deformation amount is less.

Lopes et al. [6] examined the impact concept in terms of the dispersed-stacking-sequences for the fiber-reinforced polymers. Gonzalez et al. [7] performed a simulation after the material exposed to the impact effect to make the simulation of the compression test by using the Finite Element Method. Topac et al. [8] performed a simulation by using the Finite Element Model for the [0/90]s beams by implemented impact experiments and predicted the damage of material. Soto et al. [9] realized a simulation on compression after impact and low-velocity impact. Continuum damage mechanics-based material models were used in large composite stiffened panels. Bozkurt et al. [10] performed a study to simulate a standard drop weight impact test on a [0/90/0]s composite laminates. ABAQUS was used to develop a three-dimensional virtual test setup. Greszczuk [11] recommended an analytical approach for the impact response to determine internal stresses, failure modes, and impact induced surface pressure distribution.

Nguyen et al [12] performed a review study on the capacity of the finite element software to investigate damage arising from the impact of composites. At the end of the study, it was found that commercial software has a big capacity on the concepts of creating, solve, and post-process an impact damage event. Tsartaris et al. [13] showed that internal damage caused by the low-speed effect can be examined in two categories. these are called interlaminar delamination and intralaminar transverse ply cracking.

Pekbey et al. [14] investigated the hybridization effect for nanostructured hybrid composites in terms of the impact Behavior. high strength Kevlar and S-glass fiber were used as reinforcing materials. Three types of nanomaterials with high energy absorption (nano-calcite, nano-clay, and nano-carbon tube) were used as matrix material. The plates produced with different matrix materials were arranged in various sequences and hybridization was performed.

Göv [15] performed a study to develop an algorithm to design layer and fiber number of the composite plate. stress values were used to determine fiber angle and maximum stress failure theory was used to obtain layer numbers.

Şevkat et al. [16] investigated the drop weight effect on hybrid composite plates in terms of the strain, dynamic force, and damage patterns. Flat ended, spherical, cylindrical, and straight-line impactors were used to realize the study. analysis and experimental results showed good agreement. Pekbey et al. [17] performed a study to investigate the ballistic impact performance of Kevlar composites which is filled with epoxy. Different fillers, which are nanoclay, nanocarbon, and nanocalcite were used to improve the ballistic performance of the composites.

Çakır and Berberođlu [18] investigated the mechanical properties of composite materials which are produced with vacuum supported resin transfer method and with different fiber ratios. Yanen and Solmaz [19] investigated the availability of laminates hybrid composites as armor materials. Ballistic experiments of Glass Fiber / Aramid Fiber / Carbon Fiber laminated composite plates with different fiber reinforcement angles, different sheet numbers, and different thicknesses were made and the results were examined.

In this study, the behavior of Carbon/Epoxy and Glass/Epoxy composite plates under the drop weight impact load was simulated. Composite materials have been used to have symmetrical fiber orientations. The effects of different configurations of Carbon/Epoxy and Glass/Epoxy composites on the drop weight impact loads considering 8 different inter-ply hybrid models are investigated. The thickness of the plate was increased by increasing the number of layers of the composite material and the effect of thickness increase on impact load was investigated.

## 2. Experimental Methods

### 2.1. Materials

In this study, the behavior of Carbon/Epoxy and Glass/Epoxy composite plates under the drop weight impact load was simulated. Composite materials have been used to have symmetrical fiber orientations. Each lamina of composite material that has 0.25 mm thickness. The laminate is constructed by stacking several such laminae in the direction of the lamina thickness. The used configurations are listed in Table 1. Composite materials have been used to have symmetrical fiber orientations

Table 1. Composite and hybrid composite configurations

Configurations	Thickness
$[0_G/90_G]_s$	1 mm
$[0_G/90_G/0_G/90_G]_s$	2 mm
$[0_G/90_G/0_G/90_G/0_G/90_G]_s$	3 mm
$[0_G/90_G/0_G/90_G/0_G/90_G/0_G/90_G]_s$	4 mm
$[0_C/90_C]_s$	1 mm
$[0_C/90_C/0_C/90_C]_s$	2 mm
$[0_C/90_C/0_C/90_C/0_C/90_C]_s$	3 mm
$[0_C/90_C/0_C/90_C/0_C/90_C/0_C/90_C]_s$	4 mm

Also, the effects of different configurations of Carbon/Epoxy and Glass/Epoxy composites are considered. The used inter-ply hybrid models are listed in Table 2.

Table 2. Inter-ply hybrid composite configurations

Configurations	Name
$[0_C/90_G/0_G/90_G]_s$	Model 1 (M1)
$[0_C/90_C/0_G/90_G]_s$	Model 2 (M2)
$[0_C/90_C/0_C/90_G]_s$	Model 3 (M3)
$[0_G/90_C/0_C/90_C]_s$	Model 4 (M4)
$[0_G/90_G/0_C/90_C]_s$	Model 5 (M5)
$[0_G/90_G/0_G/90_C]_s$	Model 6 (M6)
$[0_C/90_G/0_C/90_G/0_C/90_G/0_C/90_G]$	Model 7 (M7)
$[0_G/90_C/0_G/90_C/0_G/90_C/0_G/90_C]$	Model 8 (M8)

The numerical models were developed using the transient finite element module of ANSYS. Simulation of the impact event is performed by the collision of two parts, namely, the impactor and the target plate.

In accordance with the ASTM D7136/D7136M-15 [20] standard, a hemispherical impactor that has totally 5.5 kg mass and 8mm tip radius are used and as shown in figure 1 the distance between the impactor and target plate is 800 mm. In other words, the impactor is released from an 800 mm distance. The target plate dimensions are 150 mm in length and 100 mm in width. During the analyses, the impactor is taken as rigid and the target plate is taken as deformable and it is fixed from all edges (as shown in figure 1).

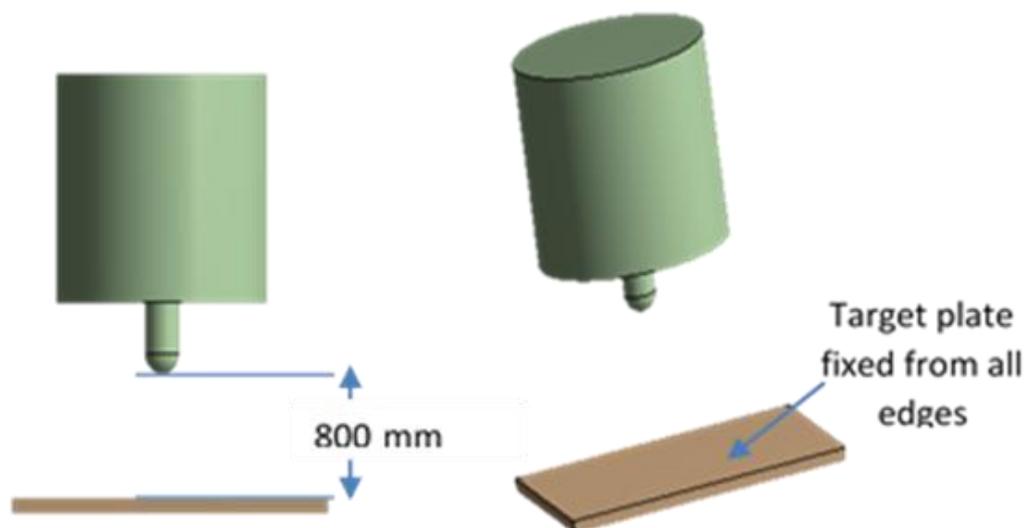


Figure 1. Impactor and target plate properties

Carbon/Epoxy and Glass/Epoxy material properties are given in Table 3.

Table 3. Material properties of Carbon/Epoxy and Glass/Epoxy [21]

<b>Material Properties</b>	<b>Carbon/Epox</b>	
	<b>y</b>	<b>Glass/Epoxy</b>
Density (mm <sup>-3</sup> t)	1,52E-09	2,00E-09
Young's Modulus X direction (MPa)	123340	50000
Young's Modulus Y direction (MPa)	7780	8000
Young's Modulus Z direction (MPa)	7780	8000
Poisson's Ratio XY	0,27	0,3
Poisson's Ratio YZ	0,42	0,4
Poisson's Ratio XZ	0,27	0,3
Shear Modulus XY (MPa)	5000	5000
Shear Modulus YZ (MPa)	3080	3846,15
Shear Modulus XZ (MPa)	5000	5000
<b>Orthotropic Stress Limits</b>		
Tensile X direction (MPa)	1632	1700
Tensile Y direction (MPa)	34	35
Tensile Z direction (MPa)	34	35
Compressive X direction (MPa)	-704	-1000
Compressive Y direction (MPa)	-68	-120
Compressive Z direction (MPa)	-68	-120
Shear XY (MPa)	80	80
Shear YZ (MPa)	55	46,1538
Shear XZ (MPa)	80	80

### 3.

### Results and Discussion

Maximum impact forces and deformations are compared for the Carbon/Epoxy and Glass/Epoxy and their hybrid models. The impact forces for Carbon/Epoxy and Glass Epoxy for different thicknesses are given in Figure 2. As seen in the figure for all thickness, the impact forces of Carbon/Epoxy are higher than the impact forces of Glass/Epoxy. The maximum impact force of Carbon/Epoxy for 1 mm plate is 1.6 times higher than the maximum impact force of Glass/Epoxy. This difference is 1.32, 1.38, and 1.45 for 2 mm, 3mm, and 4 mm thickness, respectively.

The effect of hybridization on the drop weight impact is investigated considering different hybrid models. In figure 3(a) comparisons of impact forces for the full Glass/Epoxy and hybrid models are given. These hybrid models are obtained adding 1, 2, and 3 layer carbon to the top and bottom symmetrically for full Glass/Epoxy composite. As seen in the figure, adding carbon layers increase impact loads, and obviously impact resistance of laminate is increased. The maximum difference is between M3 and Glass/Epoxy. The impact force of M3 is nearly 1.33 times higher than the impact force of Glass/Epoxy.

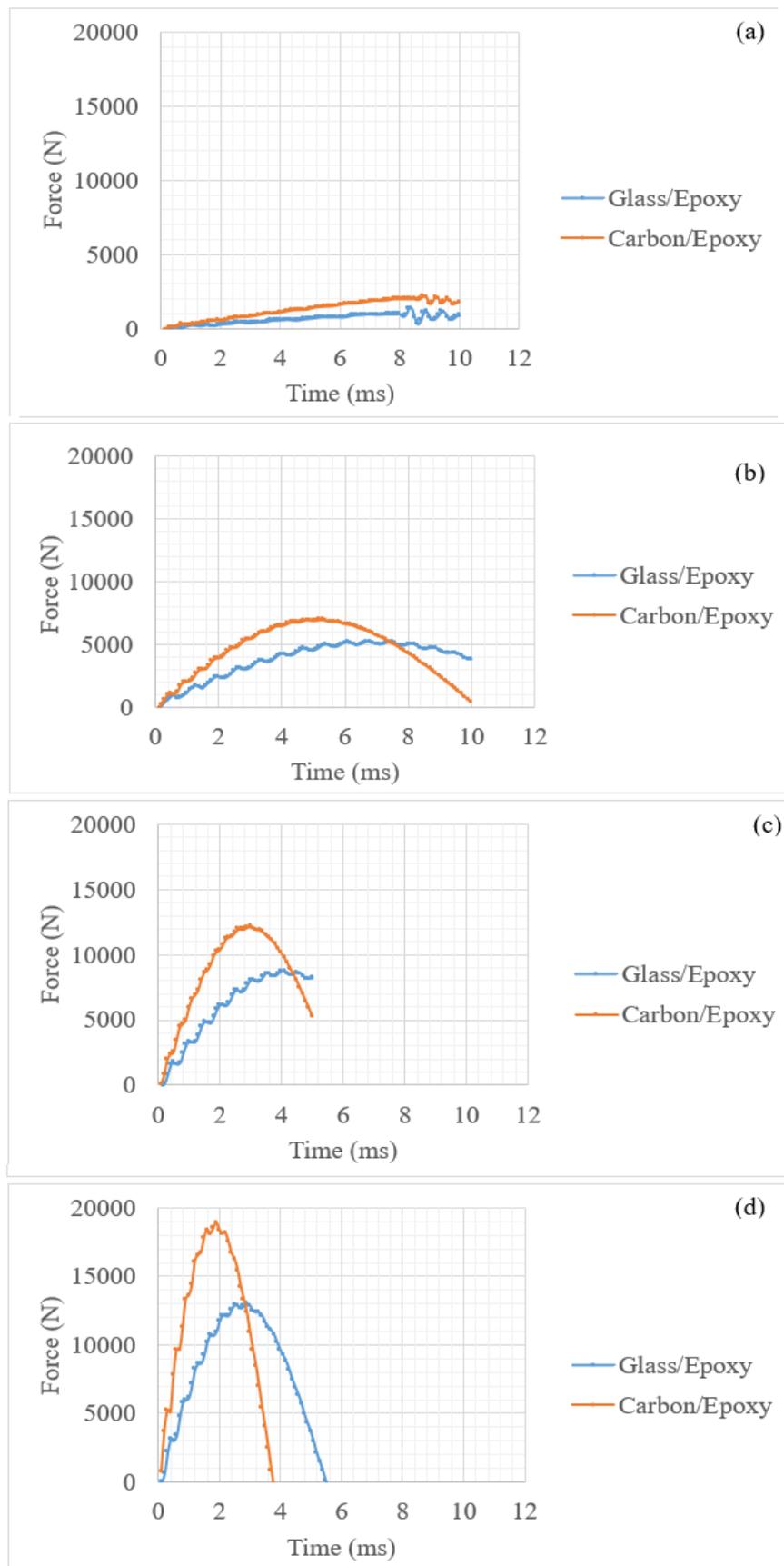


Figure 2. Variation of Impact Force of Glass/Epoxy and Carbon Epoxy composites for different thicknesses. a) 1mm, b) 2 mm, c) 3mm d) 4 mm.

In figure 3(b) comparison of impact forces for the full Carbon/Epoxy and hybrid models is given. These hybrid models are obtained adding 1, 2, and 3 layer glass to the top and bottom symmetrically for full Carbon/Epoxy composite. As seen in the figure, adding glass layers decrease the impact loads. The maximum reduction is with M6. The value of this reduction is nearly 30%

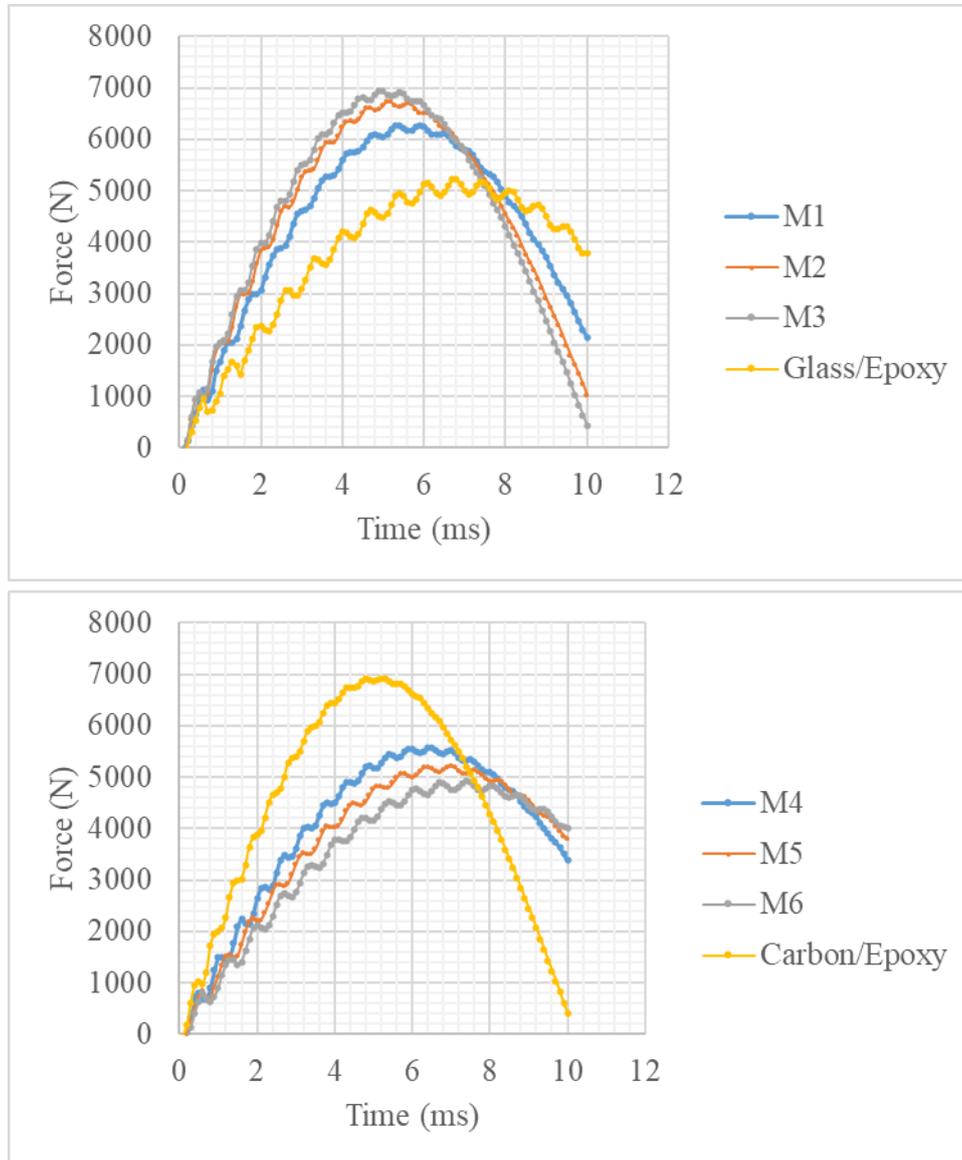


Figure 3. Variation of Impact Forces of a) Glass/Epoxy and Hybrid models b) Carbon/Epoxy and Hybrid models

Also, the hybrid configuration is obtained by adding 1 layer glass after 1 layer carbon until the getting 2mm thickness as in Model 7, and 1 layer carbon after 1 layer glass until they getting 2mm thickness as in Model 8. The comparison of these models is given in Figure 4(a). As seen in the figure, they have shown similar behavior under the drop weight impact load. In figure 4(b) comparison of one of these models with Full Glass/Epoxy and Carbon /Epoxy Laminates is given. As seen in the figure, this model has the maximum impact loads between carbon/Epoxy laminate and Glass/Epoxy laminate. Also, it is observed in this figure, the impact forces of this model closer the full Glass/Epoxy laminate than full Carbon/Epoxy laminate.

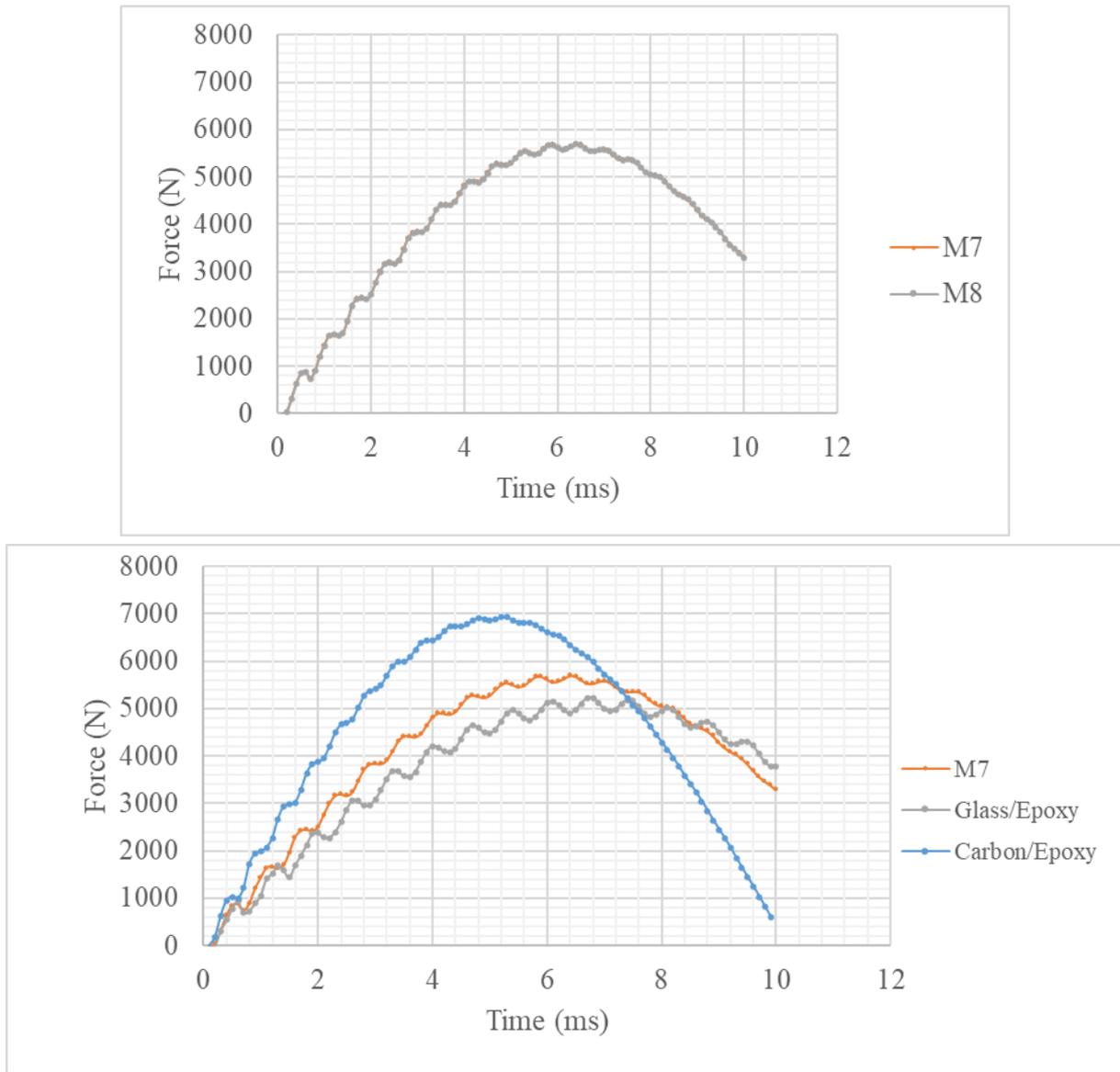


Figure 4. Comparison of Impact Forces of Hybrid composite models a) M7 and M8 b) M7 and Glass/Epoxy and Carbon Epoxy.

Figure 5 gives deformation results for 2 mm Glass/Epoxy and Carbon Epoxy composite plates. The maximum deformation of Glass/Epoxy for 2 mm plate thickness is 1.22 times higher than the maximum deformation of the Carbon/Epoxy plate.

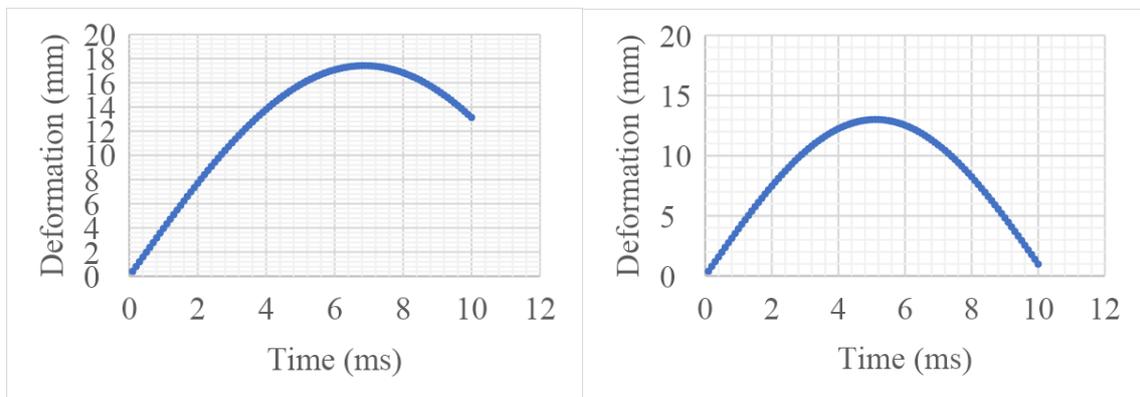


Figure 5. Deformation graph for 2 mm plate thickness a) Glass/Epoxy b) Carbon/Epoxy

In figure 6 comparison of deformation for the full glass/Epoxy and hybrid models is given. These hybrid models are obtained adding 1, 2, and 3-layer carbon to the top and bottom symmetrically for full Glass/Epoxy composite. As seen in the figure, adding carbon layers decrease the deformation, and the impact resistance of laminate is increased. The maximum difference is between M3 and Glass/Epoxy. The deformation of Glass/Epoxy is nearly 1.22 % times higher than the deformation of M3.

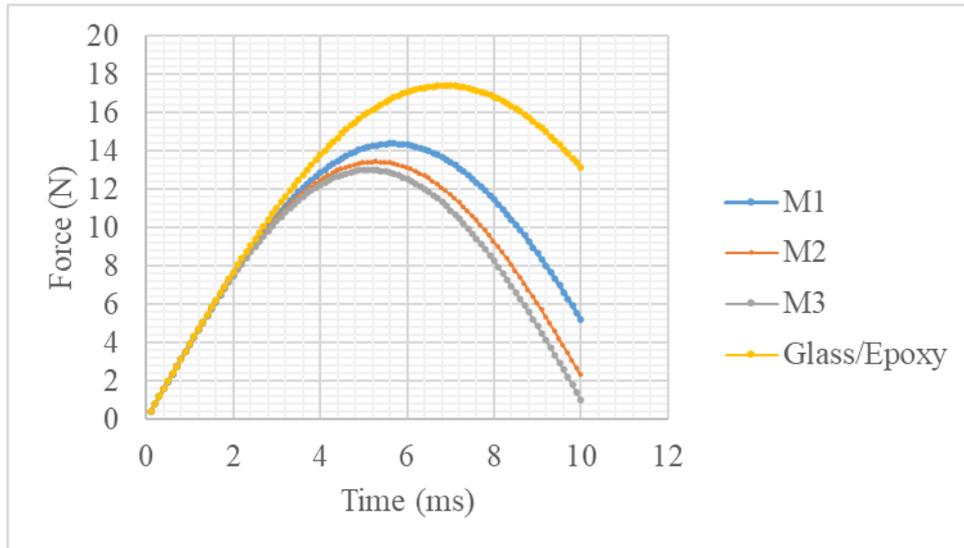


Figure 6. Comparison of deformation graph of Glass/Epoxy and hybrid models

In figure 7 comparison of deformation for the full Carbon/Epoxy and hybrid models is given. These hybrid models are obtained adding 1, 2, and 3 layer glass to the top and bottom symmetrically for full Carbon/Epoxy composite. As seen in the figure, adding glass layers increase the deformation and the impact resistance of laminate is decreased. The maximum deformation increase is with M6. The value of this increase is nearly 20%.

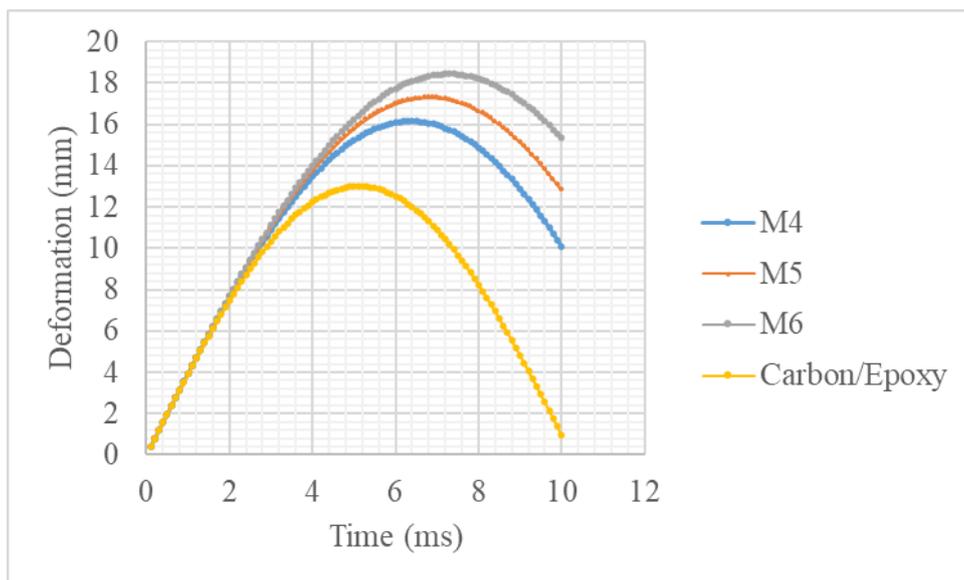


Figure 7. Comparison of deformation graph of Carbon/Epoxy and hybrid models

#### 4.

#### Conclusions

The damage resistance of Carbon/Epoxy composite plates used in the study to a drop-weight impact event better than the Glass/Epoxy composite plates used in this study. The conclusions can be summarized as:

- For the 1mm thickness, the maximum impact force of Carbon/Epoxy is 37.5 % higher than the maximum impact forces of the Glass/Epoxy.
- For the 2mm thickness, the maximum deformation of Glass/Epoxy is 18 % higher than the maximum deformation of the Carbon/Epoxy
- The effect of hybridization on the drop weight impact is investigated considering different hybrid models.
- These hybrid models are obtained adding 1, 2, and 3layer carbon to the top and bottom symmetrically for full Glass/Epoxy composite.
- Adding carbon layers increase impact loads and impact resistance of laminate is increased. The maximum difference is between M3 and Glass/Epoxy. The impact forces of M3 are nearly 1.33 times higher than the impact forces of Glass/Epoxy.
- Adding glass layers decrease the impact loads and impact resistance of laminate is decreased. The maximum reduction is with M6. The value of this reduction is nearly 30%.
- The hybrid configuration is obtained by adding 1 layer glass after 1 layer of carbon until the getting 2mm thickness as in Model 7 and 1 layer carbon after 1 layer glass until they getting 2mm thickness as in Model 8. they have shown similar behavior under the drop weight impact load.
- The maximum deformation of Glass/Epoxy for 2 mm plate thickness is 1.22 times higher than the maximum deformation of the Carbon/Epoxy plate.
- Adding carbon layers (to full Glass/Epoxy) decreases the deformation.
- Adding glass layers (to full Carbon/Epoxy) increases the deformation.

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#### References

- [1]. Villavicencio, R., and Soares, C. G., "Impact response of rectangular and square stiffened plates supported on two opposite edges", *Thin-Walled Structures*, 2013, 68: 164-182.
- [2]. Santiago, R., Cantwell W., and Alves M., "Impact on thermoplastic fibre-metal laminates: Experimental observations", *Composite Structures*, 2017, 159: 800-817.

- [3]. Rawat, P., Singh, K. K., and Nand K. S., "Numerical investigation of damage area due to different shape of impactors at low velocity impact of GFRP laminate." *Materials Today: Proceedings*, 2017, 4(8): 8731-8738.
- [4]. Yeter, E., and Dođru, M.H. "A numerical investigation on damage resistance of materials to a drop weight impact event", 3<sup>th</sup> Uluslararası Mesleki Ve Teknik Bilimler Kongresi 2018, 21-22 June.
- [5]. Yeter, E. "Damage resistance investigation of ArmoX 500T and Aluminum 7075-T6 plates subjected to drop-weight and ballistic impact loads", *Sakarya University Journal of Science*, 2019, 23(6): 1095-1080.
- [6]. Lopes, C. S., Camanho, P. P., Gürdal, Z., Maimí, P., and González, E. V., "Low-velocity impact damage on dispersed stacking sequence laminates. Part II: Numerical simulations", *Composites Science and Technology*, 2009, 69: (7-8), 937-947.
- [7]. González, E. V., Maimí, P., Camanho, P. P., Turon, A., and Mayugo, J. A., "Simulation of drop-weight impact and compression after impact tests on composite laminates", *Composite Structures*, 2012. 94: (11), 3364-3378.
- [8]. Topac, O. T., Gozluclu, B., Gurses, E., and Coker, D., "Experimental and computational study of the damage process in CFRP composite beams under low-velocity impact", *Composites Part A: Applied Science and Manufacturing*, 2017, 92: 167-182.
- [9]. Soto, A., González, E. V., Maimí, P., de la Escalera, F. M., de Aja, J. S., and Alvarez, E., "Low velocity impact and compression after impact simulation of thin ply laminates", *Composites Part A: Applied Science and Manufacturing*, 2018, 109: 413-427.
- [10]. Bozkurt, M. O., Parnas, L., & Coker, D., "Simulation of Drop-Weight Impact Test on Composite Laminates using Finite Element Method", *Procedia Structural Integrity*, 2019, 21: 206-214.
- [11]. Greszczuk, L.B., "Damage in composite materials due to low velocity impact", *Impact dynamics*, 1982, 55-94.
- [12]. Nguyen, M. Q., Elder, D. J., Bayandor, J., Thomson, R. S., & Scott, M. L., "A review of explicit finite element software for composite impact analysis" *Journal of Composite Materials*, 2005, 39(4): 375-386.
- [13]. Tsartaris, N., Dolce, F., Polimeno, U., Meo, M., Guida, M., Marulo, F., Riccio, M., "Low velocity impact behavior of fibre metal laminates", in: *Proceedings of the 7<sup>th</sup> International Conference on Composite Science and Technology*, 2009, 20–22 January.
- [14]. Yumak, N., Aslantaş, K., and Pekbey, Y., "The Effect of Hybridization on the Ballistic Impact Behavior of Nanostructured Hybrid Composite Plates", *El-Cezeri Journal of Science and Engineering*, 2019, 7(1): 124-134.
- [15]. Göv, İ., "A novel approach for design of fiber angle and layer number of composite plates", *Polymer Composites*, 2017, 38(2): 268-276.
- [16]. Sevkat, E., Liaw, B., & Delale, F., "Drop-weight impact response of hybrid composites impacted by impactor of various geometries", *Materials & Design* 2013, 52: 67-77.
- [17]. Pekbey, Y., Aslantaş, K., & Yumak, N., "Ballistic impact response of Kevlar Composites with filled epoxy matrix", *Steel and Composite Structures*, 2017, 22(4): 191-200.
- [18]. Çakir, M., & Berberođlu, B., "E-Cam Elyaf Takviyeli Epoksi Matrisli Kompozit Malzemelerin Elyaf Oranındaki Artış İle Mekanik Özelliklerindeki Deđişimlerin İncelenmesi", *El-Cezeri Journal of Science and Engineering*, 2018, 5(3): 734-740.
- [19]. Yanen, C., & Solmaz, M. Y., "Tabakalı Hibrit Kompozitlerin Bireysel Zırh Malzemesi Olarak Üretimi Ve Balistik Performanslarının İncelenmesi", *El-Cezeri Journal of Science and Engineering*, 2016, 3(2): 351-362.
- [20]. ASTM D7136/D7136-15. Standard test method for measuring the damage resistance of a fiber reinforced polymer matrix composite to a drop weight impact event, 2015.
- [21]. ANSYS material library.

