Kerbala Journal for Engineering Science
https://kjes.uokerbala.edu.iq/

New Approach on Improving Mechanical Properties of Hybrid Composite by Adding Mica as Natural Fiber with Glass Fiber Reinforced Epoxy Composites

Mohammed Rashad Ibrahim [a]*, Gailan Ismail Hassan [a]

[a] Department of Mechanical & Energy Engineering, Erbil Technical Engineering College, Erbil Polytechnic University, Erbil, Iraq.
* Corresponding author, Email: mohammed.rashad1993@gmail.com

Received: 29 July 2022; Revised: 08 December 2022; Accepted: 31 March 2023, Published: 31 March 2023

Abstract

A new attempt development of new hybrid composite materials has been studied. Increasing the mechanical and physical properties of composite materials to lower their weight and cost is the most frequent problem in engineering projects. This study's goal is to enhance the mechanical and physical characteristics of composite materials. Also due to this, hybrid composite materials have received recent attention. In this work, hybrid composite materials were created to enhance mechanical and physical characteristics. In this investigation, glass fiber and mica fiber were both employed as synthetic and natural fibers, respectively. The influence of mica as natural fiber with glass fiber as synthetic reinforcement by weight percent (wt%) on the mechanical properties of hybrid composite materials were investigated. Epoxy resin (thermosetting polymer) reinforced by various wt % of glass fiber/mica fiber, such as (0-0, 15-0, 10-5, 7.5-7.5, 5-10, 0-15 %), as well as samples created by hand lay-up method. In addition, glass fiber and mica fiber in long fiber unidirectional form are utilized; mechanical properties such as tensile, flexural and impact strength have been tested. As the results of this study, both glass fiber and mica fiber increased mechanical properties, although glass fiber has a greater effect than mica fiber but also using mica fiber make great improvement between 26% to 67%. Composites reinforced with 15% glass fiber had a better value of mechanical properties compared to others. Additionally, the hybrid composite made of glass fiber and mica fiber performed well in all tests, enhanced mechanical characteristics, which decreased the cost of making composites.

Keywords: Mechanical properties, hybrid composites, Mica fiber, Glass fiber

1. Introduction

Composites have become an increasingly important aspect of today's materials due to benefits such as low lightweight, resistance to corrosion, high fatigue strength, etc… [1]. Composite materials utilizing natural fibers as reinforcing components have recently received much attention in a wide range of sectors [2]. Natural fiber has various advantages such as low density, biodegradability, low cost, reduced energy consumption and less health risk, which is why it is increasingly being used in composite materials. Cotton, hemp, abaca, jute, kenaf, flax, sisal and other natural fibers are some of the options [3]. These composite materials have been employed in a variety of sectors, including aircraft, leisure, construction, sport, packaging and vehicle sectors [4]. As a solution to the environmental issue and reduce costs when designing composite materials, natural fiber may play a significant role. Natural fibers are lighter and less expensive than synthetic fibers, but they have lower mechanical properties. Hybrid composites are a promising choice for tackling this problem in new advanced composites [5].

Cotton fibers, among the natural fibers obtainable, have excellent properties such as high strength and durability, as well as absorbency and biodegradability. This fibers contain the largest molecular weight cellulose of any plant fiber, chemical composition contains (88-96% cellulose), (0.7-1.2 % pectic), (1.1-1.9 % Protein) (0.4-1 % wax) and (0.7-1.6 % ash)[6]. As a result, polymer composites based on cotton fibers have played an increasingly important role in specific applications, including the automobile sector and also in terms of strength requirements. The fundamental drawback of these composites is the insufficiency fiber–matrix interface adhesion, which has a negative impact on composite properties [7], also cotton is one of the most widely produced textile fibers for commercial use worldwide [8].

Adding natural fibers and synthetic fibers to polymer composites has enhanced their mechanical and physical properties in various researches. Cotton fiber, one of their fibers, has also been employed in other studies, including; [9] in their study, by adding cotton fibers to geopolymer composites, the flexural strength of the composites was enhanced by 12.5 %, also when the percentage of cotton fiber in composites increased, the density of the composites declined. [10] in their study, they created composite materials with cotton fibers that reinforced polypropylene resin. They demonstrated that the composite material's tensile strength has been enhanced (36%). Other studies [11] found that adding cotton fiber to poly (ethylene terephthalate), increased mechanical properties such as flexural strength, tensile strength and impact resistance. Cotton fiber, on the other hand, has been combined with different fibers in various studies to improve mechanical properties. [12] in their study, to increase the mechanical properties of phenolic resin, cotton fiber was combined with jute fiber with various orientations. They found that composites' mechanical properties have improved, with the highest values of (flexural strength, tensile strength and impact resistance) attained with (0^o).

This review show that mica (Phenolic Cotton Laminated) fiber have never been used in fabrication and preparing of epoxy based composite except our attempts to use it in this study. In the current study, the thermosetting polymer is reinforced with mica fiber and/or glass fiber. Tensile, flexural strength and impact resistance properties of the composites were evaluated at different weight fractions of fibers. The main objective of this research is to enhance the mechanical and physical properties of composite materials, as well as to develop a cost-effective natural fiber for a wide range of applications.

2. Experimental

2.1 Materials

In this work, employed various materials to create composite materials such as:

i. Epoxy resin: we employed two epoxy resins in our investigation (Sikadur-31 DW and MasterBrace ADH 1420). Sikadur 21 DW is made up of two parts resin and hardener that must be mixed in a 3/1 ratio by volume or weight, with a mixing density of 2kg/l. MasterBrace ADH 1420 is made up of two parts resin and hardener that must be mixed at a ratio of 2/1 by weight or volume, with a mixing epoxy density of 1.55 kg/l.

ii. Mica fiber (Phenolic Cotton Laminated Rod): the phenolic cotton laminated rod is composed of many layers of cotton fabric that were molded and processed under pressure and heat and are coated with phenolic resin. The stiff laminated rods are then cured in various diameter molds at high pressures and temperatures. We collected some size from mica fiber by using a wood wool machine, and then divided it into (long fiber, particle, powder) forms using mechanical sieving. Table 1 shows the physical and mechanical properties of mica fiber.

(a) **(b)**

Figure 1 (a) Mica fiber (Phenolic Cotton Laminated Rod), (b) Mica fiber after grinding by a wood wool machine.

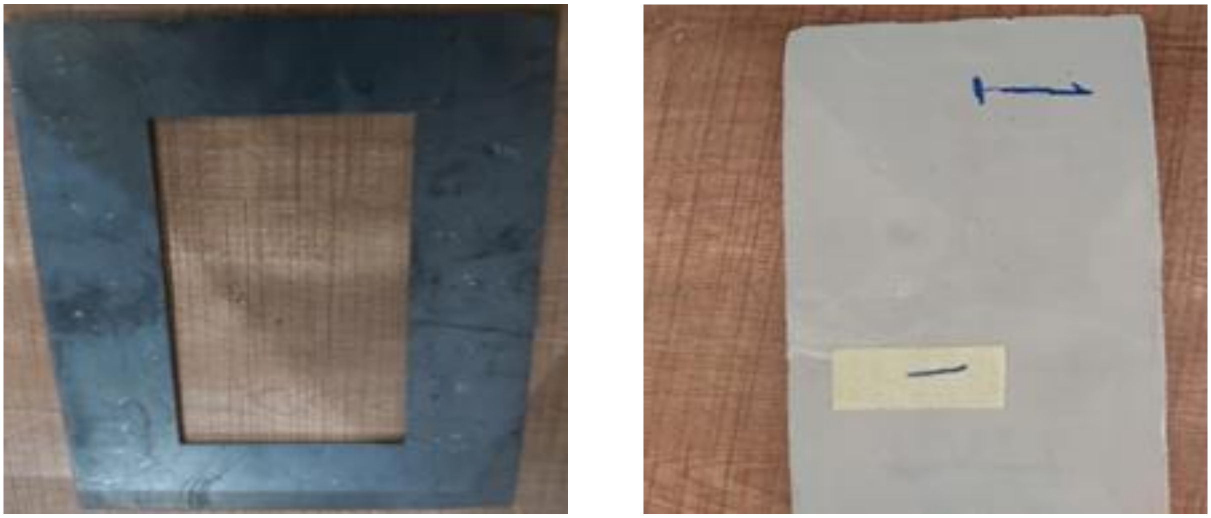
iii. Glass fiber: in this study, we used E6-glass fiber 368T direct roving. The physical and mechanical parameters of glass fiber are shown in Table 1.

Table 1 Physical and mechanical property of mica fiber and glass fiber. [13]

Parameter	**Mica fiber**	**Glass fiber**
Density g/cm^3	1.25-1.4	2.62
Diameter	5 (cm)	21-22 (μm)
Tensile strength (MPa)	78	2741
Flexural strength (MPa)	95	…..
Limit temperature (°c)	120	15-35

2.2 Preparation of composites materials.

Steel plate was used for the preparing moulds for the fabrication composite materials, having the dimensions of (200-100-3 mm) as shown in figure 2. The samples has been prepared by hand lay-up, the epoxy was mixed with hardener at a 3/1 ratio for Sikadur-31 DW and 2/1 for MasterBrace ADH 1420 and the resin was mixed for 3 minutes to ensure homogeneity.



(a) **(b)**

Figure 2 (a) Steel plate moulds, (b) Samples after removing from moulds.

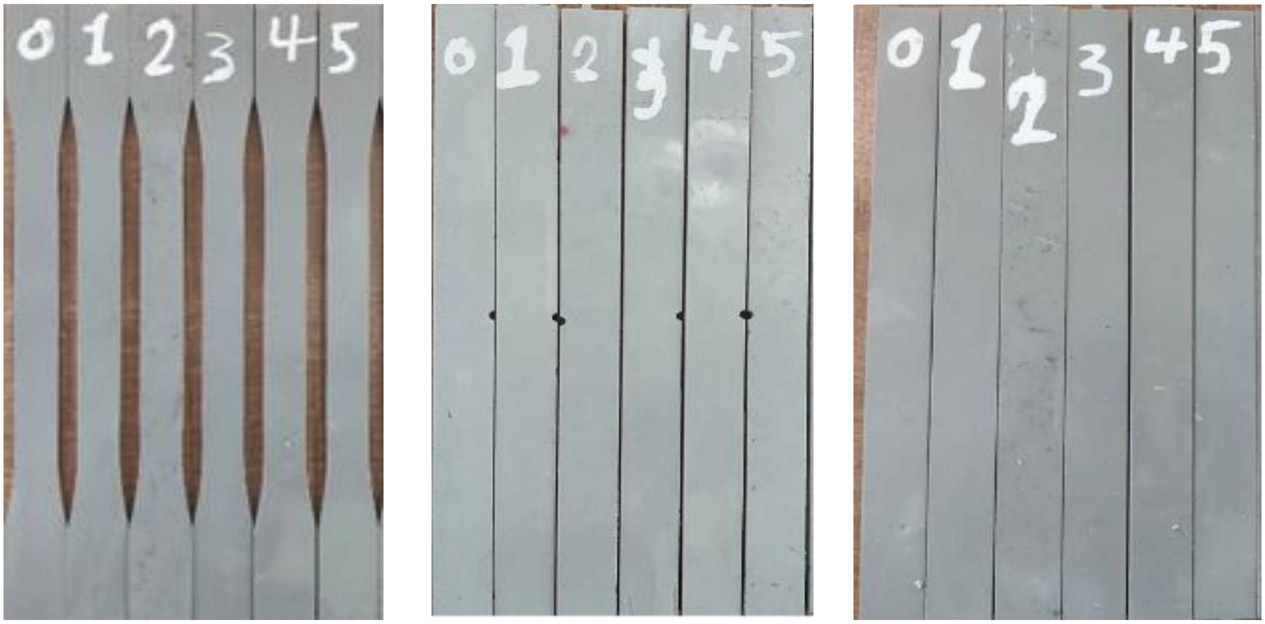
After pouring the required amount of epoxy resin over the moulding, the glass fiber was placed unidirectionally over the epoxy resin, epoxy resin was poured over the glass fibers at second time, the second layer glass fiber was placed unidirectionally over the epoxy resin and finally epoxy resin was poured over it. This process is used for fiber glass composites and mica fiber composites, however for hybrid composites; the initial layer of glass fiber is replaced with mica fiber. All samples were pressed by 15kg at room temperature, and then kept in this state during 4 hours for Sikadur-31 DW and 24 hours for MasterBrace ADH 1420 before being removed from the mould. Auto-Cad software was used to construct the dimensions of the (tensile, flexural and impact samples). The dimensions were then used to create a Computer Numerical Control (CNC) water jet that cut samples. The content of composite materials was shown in table 2.

Table 2 the composition of composite materials.

#	Epoxy weight (g)	FG weight %	Mica Fiber weight %
S0,M0	100%	0	0
S1,M1	85%	15%	0
S2,M2	85%	10%	5%
S3,M3	85%	7.5%	7.5%
S4,M4	85%	5%	10%
S5,M5	85%	0	15%

Where S= Sikadur-31 DW composites, M= MasterBrace ADH 1420 composites

In addition, figure 3 depicts the sample for each test after being cut using a CNC water jet.



(a) **(b)** **(c)**

Figure 3 (a) Tensile test samples, (b) Impact test samples, (c) Flexural test samples.

2.3 Mechanical tests

The tensile test specimen was manufactured in accordance with ASTM D638[14] standard with dimensions of (165-19-3 mm) as shown in figure 4. Tensile tests were performed using the salahaddin universal testing machine in accordance with ASTM D638 at a rate of 5 mm/min. The samples' flexural properties were determined using ASTM D790[15], a three-point flexural test technique for unreinforced and reinforced polymers. The flexural tests were done on the koya universal testing machine according to ASTM D790 with the crosshead speed of 5 mm/min and the span length is 80mm the dimensions of specimen used are (130-12.7-3 mm) which showed in figure 4. The charpy impact test machine was used to conduct the tests and the salahaddin universal testing machine was utilized to conduct the tests in accordance with ASTM D6110[16]. The dimensions of the specimen used were (127-12.7-3 mm), as shown in figure 4.

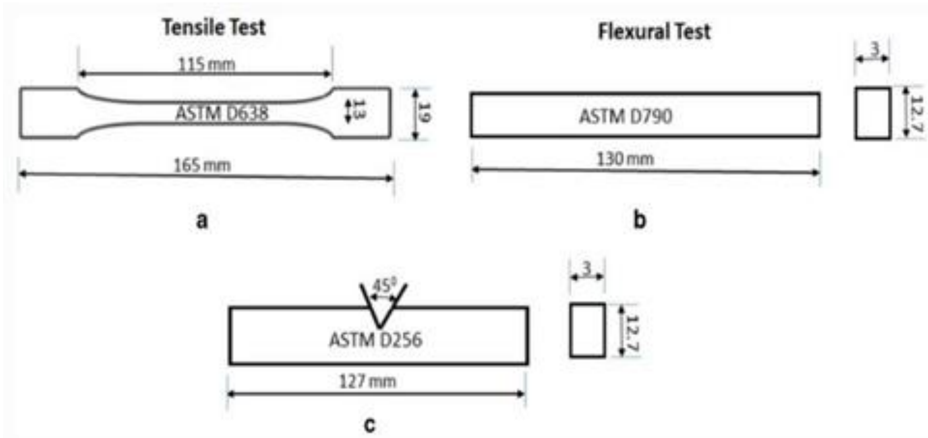


Figure 4 (a) ASTM D638 standard for tensile samples. (b) ASTM D790 standard for flexural samples. (c) ASTM D256 standard for impact charpy samples.

Also, in figure 5 showed some samples broken after mechanical testing like (tensile, flexural and impact strength).

(a) (b) (c)

Figure 5 (a) Tensile samples after testing, (b) Impact samples after testing, (c) Flexural samples after testing.

3. Results and discussion:

In this study, conducted three mechanical properties for composite materials (tensile, flexural and impact strength), all of them were conducted in accordance with ASTM standards. Tables 3 and 4 illustrate the results of their composite material testing.

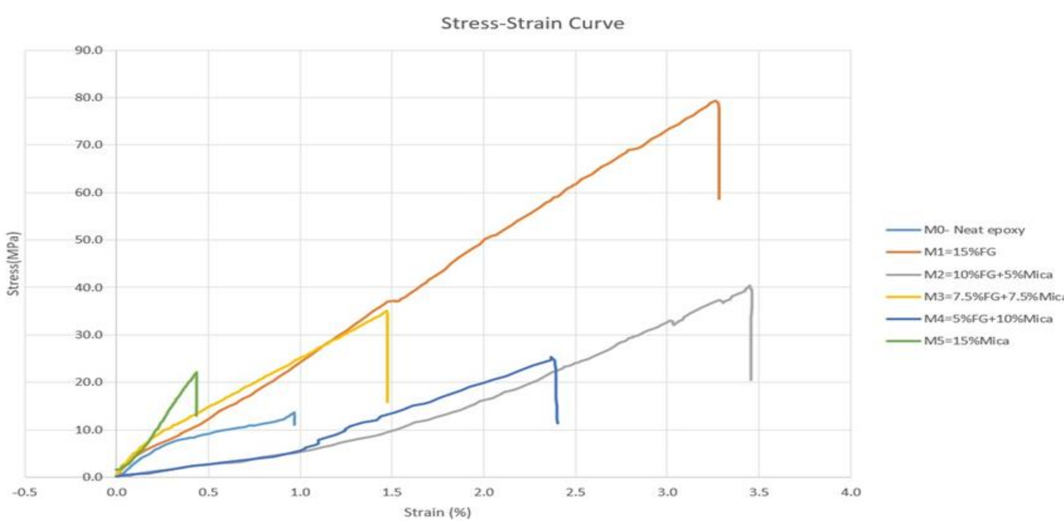
Table 3 shows the result tests of composite materials master brace.

Tests	M0	M1	M2	M3	M4	M5
Tensile strength (MPa)	13.7	79	40	35	25	23
Flexural strength (MPa)	30.95	132.88	108.98	80.477	53.42	44.84
Impact energy (J)	0.88	3.565	2.411	2.092	1.583	1.11

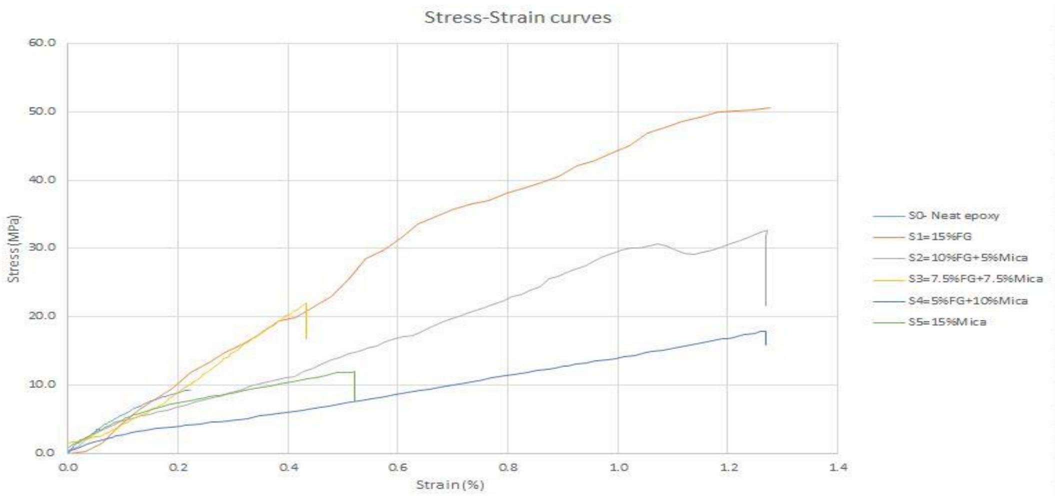
Table 4 shows the result tests of composite materials sikadur.

Tests	S0	S1	S2	S3	S4	S5
Tensile strength (MPa)	9.5	54	33	22	18	11
Flexural strength (MPa)	23.3	111.99	81.51	63.01	40.69	34.04
Impact energy (J)	0.225	1.888	1.375	0.765	0.426	0.340

Figure 6 shows how tensile strength changes with different content of composite materials, we observed that each composites glass fiber and mica fiber had improved the tensile strength of epoxy resins, and also it can able to be seen that glass fiber composites show higher tensile strength compared to mica fiber composites which is related to the nature of synthetic fiber in comparing with natural fiber, the best value of tensile strength achieved with (S1,M1) which reinforced by (15%) of glass fibers, Sikadur epoxy resin climbed by 460 %, while master brace epoxy resin increased by 470 %. Due to the strong mechanical properties of glass fiber, tensile strength decreases as the wt.% of glass fiber decreases. The tensile strength of epoxy resin was also improved by 15% for sikadur epoxy resin and 67% for master brace epoxy resin when mica fiber was reinforced.



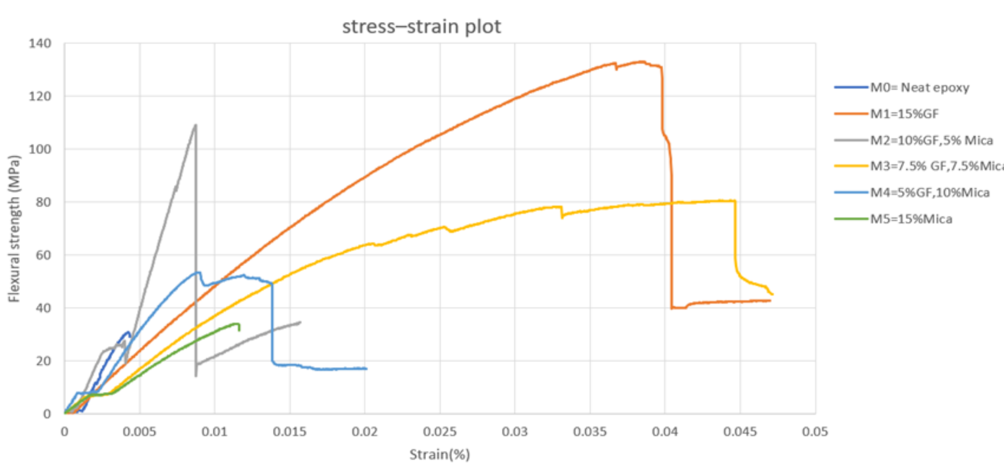
(a)



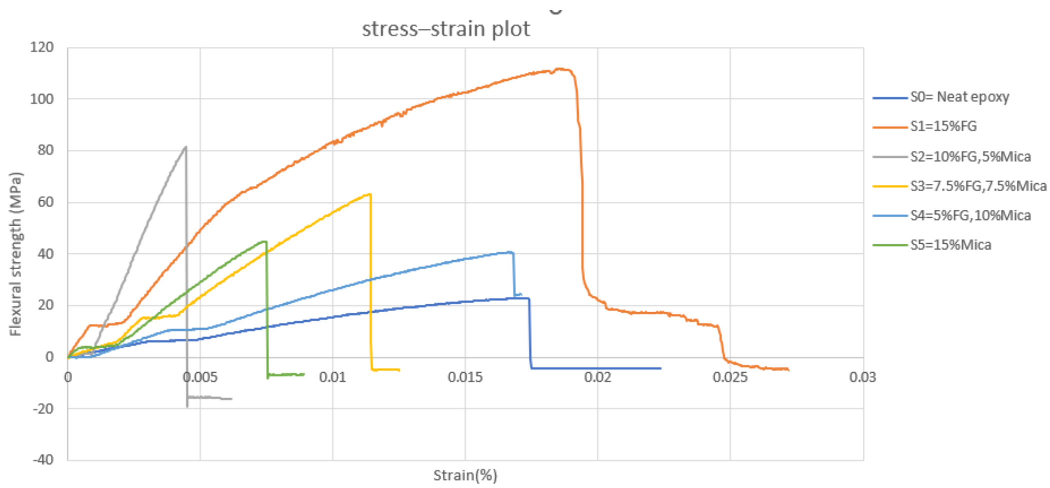
(b)

Figure 6 (a) The result of tensile strength composite materials master brace. (b) The result of tensile strength composite materials sikadur.

Figure 7 demonstrates the relation between flexural strength and fiber content of composite materials. The neat epoxy composite materials obtained 23.3 MPa for sikadur composites and 30.95 MPa for master brace composites. However, by adding 15% glass fiber to neat epoxy, the flexural strength dramatically increased and reached 111.99 MPa (380%) for sikadur epoxy and also reached (132.88 MPa) (329%) for master brace epoxy. Also due to the strong mechanical properties of glass fiber and the use of glass fiber unidirectionally, good interface adhesion between matrix and fibers occurred, but flexural strength decreased linearly as the wt% of glass fiber was reduced. Using mica fiber also increased flexural strength, reaching (34.04 MPa) (46 %) for sikadur epoxy and (44.84 MPa) (44.87 %) for master brace epoxy.



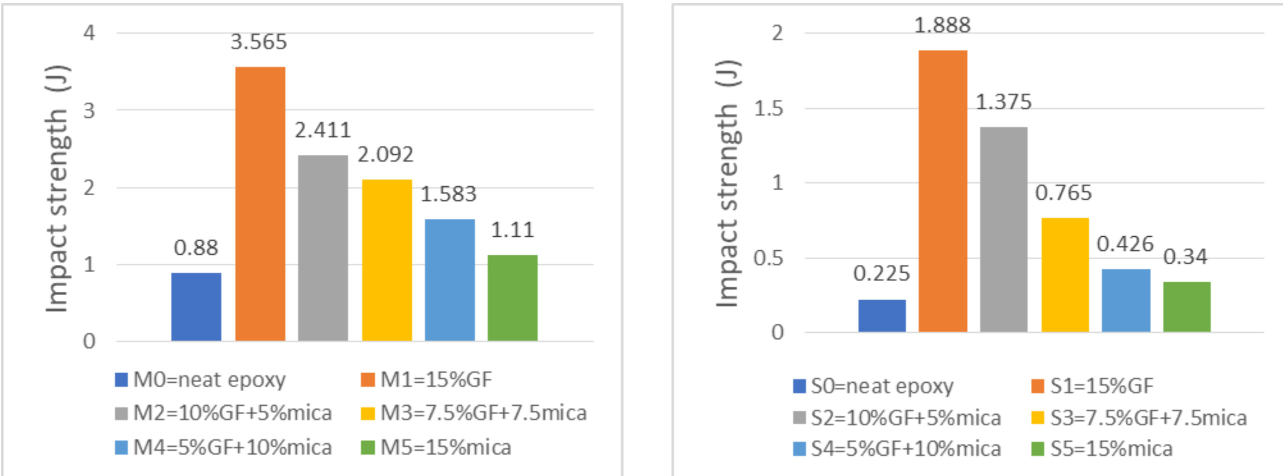
(a)



(b)

Figure 7 (a) The result of flexural strength composite materials master brace. (b) The result of flexural strength composite materials sikadur.

Figure 8 illustrates the effect of fiber loading on the impact strength of mica and glass fiber and hybrid fiber reinforced epoxy composites. We can also see that the increasing wt % has a large impact on the mechanical properties of glass fiber composites, due to the same reasons discussed in tensile and flexural strength, adding glass fiber to epoxy composites dramatically increases impact resistance from (0.225 J) to (1.888 J) approximately (700 %) for sikadur composites, and from (0.88 J) to (3.565 J) approximately (300 %) for master brace composites. Mica fiber also improved the impact strength of epoxy composites, with sikadur composites improving to (0.34J) about (51%), and master brace composites improving to (1.11) approximately (26%).



(a) **(b)**

Figure 8 (a) The result of impact strength composite materials master brace. (b) The result of impact strength composite materials sikadur.

6. Conclusion

Mica fiber, which is a natural fiber, had been used for the first time in this study, and/or glass fiber, which is a synthetic fiber was used to reinforce epoxy composites (thermosetting polymer). Additionally, these fiber-reinforced epoxy composites may be made with single fibers or mixed fibers, such as hybrid fibers. For this composite, three mechanical properties experiments were conducted, and we were able to gain some results, which are discussed in the current work, few points can be concluded as below:

i. Both fibers enhanced the tensile strength of both epoxies, due to the strong mechanical properties of glass fiber, glass fiber composites achieved greater tensile strength than mica fibers predictably, the best tensile value was found with (M1 and S1), which were reinforced with 15% glass fiber.

ii. We attain the same results for flexural strength in coincidence with tensile strength, the best value of flexural strength obtained when composites reinforced with 15% glass fiber.

iii. In the Charpy impact test, composites reinforced with 15% glass fiber got the best value. Mica fiber raised the impact strength of composites as well, but it had a smaller impact value than glass fibers.

iv. Mechanical properties (tensile strength, flexural and impact resistance) of composite materials master brace (ADH 1420 Composite) it is higher than composite material sikadur (31 DW composite). Coincidence with that the effects of mica fiber were more apparent in composite master brace.

v. Although glass fiber has a greater effect than mica fiber for (tensile strength, flexural and impact resistance) as expected, but also using mica fiber make great improvement between 26% to 67%. For all of them.

vi. By properly fabricating mica fiber reinforced epoxy composites, this work offered opportunity to use mica fiber with glass fiber in reinforced thermosetting polymers with light weight composites to discover an appropriate cost-performance balance and ecologically acceptable material.

vii. Fabrications of composite materials raw ingredients for polymers are costly. As a result, we may recycle mica fiber that was previously utilized in their application, lowering the cost of raw materials.

References:

[1] S. Ekşi and K. Genel, "Comparison of Mechanical Properties of Unidirectional and Woven Carbon, Glass and Aramid Fiber Reinforced Epoxy Composites," *Acta Phys. Pol. A*, vol. 132, no. 3, pp. 879–882, 2017, doi: 10.12693/APhysPolA.132.879.

[2] Z. Ren *et al.*, "Effect of Alkali Treatment on Interfacial and Mechanical Properties of Kenaf Fibre Reinforced Epoxy Unidirectional Composites," *Sains Malaysiana*, vol. 48, no. 1, pp. 173–181, 2019, doi: 10.17576/jsm-2019-4801-20.

[3] A. V Abhijith, A. Dharmarajan Thayyil, and T. Narendiranath Babu, "Tensile Behavior of Lotus Natural Fiber and E-Glass Fibers Reinforced with Epoxy Composites," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1123, no. 1, p. 012034, 2021, doi: 10.1088/1757-899x/1123/1/012034.

[4] H. Ku, H. Wang, N. Pattarachaiyakoop, and M. Trada, "A Review on the Tensile Properties of Natural Fiber Reinforced Polymer Composites," *Compos. Part B Eng.*, vol. 42, no. 4, pp. 856–873, 2011, doi: 10.1016/j.compositesb.2011.01.010.

[5] M. R. Sanjay, G. R. Arpitha, and B. Yogesha, "Study on Mechanical Properties of Natural - Glass Fibre Reinforced Polymer Hybrid Composites: A Review," *Mater. Today Proc.*, vol. 2, no. 4–5, pp. 2959–2967, 2015, doi: 10.1016/j.matpr.2015.07.264.

[6] J. Koh, “Dyeing of cellulosic fibers,” *Handb. Text. Ind. Dye. Vol. 2 Appl. Dye.*, pp. 129–133, Dec. 2011, doi: 10.1533/9780857094919.1.129.

[7] N. Chand and M. B. T.-T. of N. F. P. C. Fahim, Eds., “5 - Cotton Reinforced Polymer Composites,” in *Woodhead Publishing Series in Composites Science and Engineering*, Woodhead Publishing, 2008, pp. 129–161.

[8] C. G. Silva, D. Benaducci, and E. Frollini, “Lyocell and Cotton Fibers as Reinforcements for a Thermoset Polymer,” *BioResources*, vol. 7, no. 1, pp. 78–98, 2012.

[9] T. Alomayri, F. U. A. Shaikh, and I. M. Low, “Characterisation of Cotton Fibre-Reinforced Geopolymer Composites,” *Compos. Part B Eng.*, vol. 50, pp. 1–6, 2013, doi: 10.1016/j.compositesb.2013.01.013.

[10] R. Petrucci *et al.*, “Tensile and Fatigue Characterisation of Textile Cotton Waste/Polypropylene Laminates,” *Compos. Part B Eng.*, vol. 81, pp. 84–90, 2015, doi: 10.1016/j.compositesb.2015.07.005.

[11] Y. Zou, N. Reddy, and Y. Yang, “Reusing Polyester/Cotton Blend Fabrics for Composites,” *Compos. Part B Eng.*, vol. 42, no. 4, pp. 763–770, 2011, doi: 10.1016/j.compositesb.2011.01.022.

[12] E. S. De Medeiros, J. A. M. Agnelli, K. Joseph, L. H. De Carvalho, and L. H. C. Mattoso, “Mechanical Properties of Phenolic Composites Reinforced with Jute/Cotton Hybrid Fabrics,” *Polym. Compos.*, vol. 26, no. 1, pp. 1–11, 2005, doi: 10.1002/pc.20063.

[13] L. Henan YAAN Electrical Insulation Material Plant Co., “https://www.yaanelectric.com/tube/85.html.” .

[14] “ASTM D 638 − 14 Standard Test Method for Tensile Properties of Plastics,” 2015.

[15] “ASTM D790-15 Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials,” 2016.

[16] “ASTM D6110-10 Standard Test Method for Determining the Charpy Impact Resistance of Notched Specimens of Plastics,” 2018.

نهج جديد لتحسين الخصائص الميكانيكية للمركب الهجين عن طريق إضافة الميكا كألياف طبيعية مع مركبات الإيبوكسي المقواة بالألياف الزجاجية

الخلاصة: *تمت دراسة نهج جديد لتطوير مواد مركبة هجينة جديدة. تعتبر زيادة الخواص الميكانيكية والفيزيائية للمواد المركبة لخفض وزنها وتكلفتها هي المشكلة الأكثر شيوعًا في المشاريع الهندسية. تهدف هذه الدراسة إلى تعزيز الخصائص الميكانيكية والفيزيائية للمواد المركبة. بسبب هذا أيضًا ، حظيت المواد المركبة الهجينة باهتمام حديث. في عملنا ، تم إنشاء مواد مركبة هجينة لتحسين الخصائص الميكانيكية والفيزيائية. في هذا التحقيق ، تم استخدام كل من الألياف الزجاجية وألياف الميكا كألياف طبيعية وصناعية ، على التوالي. تم دراسة تأثير الميكا كألياف طبيعية مع الألياف الزجاجية كمقويات اصطناعية بنسبة الوزن (بالوزن٪) على الخواص الميكانيكية للمواد المركبة الهجينة. راتنجات الايبوكسي (بوليمر متصلب بالحرارة) معززة بنسبة وزن مختلفة من الألياف الزجاجية / ألياف الميكا ، مثل (0-0 ، 15-0 ، 10-5 ، 7.5-7.5 ، 5-10 ، 0-15٪) ، وكذلك العينات تم إنشاؤها بطريقة وضع اليد. بالإضافة إلى ذلك ، يتم استخدام الألياف الزجاجية وألياف الميكا في شكل ألياف طويلة أحادية الاتجاه ؛ تم اختبار الخواص الميكانيكية مثل قوة الشد والانثناء والتأثير. نتيجة لهذه الدراسة ، زادت الألياف الزجاجية وألياف الميكا من الخصائص الميكانيكية ، على الرغم من أن الألياف الزجاجية لها تأثير أكبر من ألياف الميكا ولكن أيضًا باستخدام ألياف الميكا تحسن بشكل كبير بين 26٪ إلى 67٪. كانت المركبات المقواة بنسبة 15٪ من الألياف الزجاجية ذات قيمة ميكانيكية أفضل مقارنة بغيرها. بالإضافة إلى ذلك ، كان أداء المركب الهجين المصنوع من الألياف الزجاجية وألياف الميكا جيدًا في جميع الاختبارات ، مما أدى إلى تحسين الخصائص الميكانيكية ، مما قلل من تكلفة صنع المركبات.*