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Effect on the Impact Strength of Glass/Flax Fiber Reinforced Epoxy Composite with Novel Aluminum oxide+Glass Beads Nanoparticles

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Abstract

Aim: The aim of the research is to investigate the impact strength of hybrid glass and flax fiber reinforced composite with and without novel Al_2O_3+glass beads nanoparticles filler materials. **Materials and Methods:** The hand lay-up method is used to make hybrid composites in two groups. Glass/Flax fiber reinforced epoxy composite without novel Al_2O_3+glass beads filler specimens as control group(CG) and glass/flax fiber reinforced epoxy composite with 4 wt.% novel Al_2O_3+glass beads filler specimens as experimental group(EG). The G power used for this process is 80%, α = 0.05 per set for calculating sample size of two groups and total sample size calculated is 40 using ClinCalc. The ASTM-D256 standard was used to prepare these sample groups. The Standard V-notch Izod impact test is used to determine the impact strength of each group with and without filler materials. An independent sample t-test is used to analyze and compare the test findings and its statistical significance. **Results:** The impact strength of samples with and without the novel Al_2O_3+glass beads filler is compared using test data.. In comparison to samples without filler, the impact strength of samples made with filler is higher. The test findings generated with SPSS v26 software have a significance of $p=0.001(p<0.05)$. **Conclusion:** Within the limits of the study hybrid composite with 4 wt.% novel Al_2O_3+glass beads filler possesses a higher impact strength of 15.9% than the composites made without filler material.

Keywords

Natural Fiber, Glass Fiber, Flax Fiber, Novel Al_2O_3+Glass Beads, Izod Test, Hybrid Composite, Hand Layup Method.

INTRODUCTION

Materials that are inexpensive, light, and robust are required in today's environment. Composite items can now meet these requirements. They have a good weight-to-strength ratio, making them a lightweight and powerful material. Hybridization is a prominent process for improving composite material characteristics (Swolfs, Gorbatikh, and Verpoest 2014). The properties of a composite material are enhanced when it is combined with a matrix material, such as an epoxy polymer (Romanzini et al. 2013). The demand for new and alternative material is increasing in our daily life. These composites are used in automotive industries and also in development of aerospace applications (Mangino, Carruthers, and Pitarresi 2007). Glass and flax natural fiber, as well as a polymer matrix, are used in this paper as composite materials. Just a few papers were chosen from the studies conducted in the previous five years. Researchers also found that composites with a low fiber content and a high glass and flax fiber fraction have a higher potential for adhesion. Owing to the increased glass and flax fiber fraction, mechanical properties such as izod Impact Strength and shear strength improved as well (Quagliarini and Lenci 2010; Taha and Ziegmann 2006). The use of glass and flax fibers as reinforcement in hybrid composites is justified due to their superior mechanical properties as compared to other natural and synthetic fibers. In the composites tested, the glass and flax fiber resulted in better mechanical properties. The Impact properties strengthen as the volume fraction of glass fiber increases, according to studies (Romanzini et al. 2012; Giridharan 2019). Glass and flax fiber has proved to be an excellent material for manufacturing low-cost composites. Fiber reinforced composites were hybridized at two separate weight ratios, and samples were prepared and tested to determine their properties. The mechanical properties of the Hybrid Fiber Reinforced Epoxy Composite (HFREC) were improved, including, flexural strength, and izod impact strength (Romanzini et al. 2012).

From the literature survey done we have found 1482 articles in Google scholar and 754 articles in Sciencedirect similar to our research work. Now the growing trend in this area motivated us to pursue this project. The usage of the natural fiber tends to improve the mechanical properties of the composite and also show a certain increase in the impact strength of the polymer composite ((Sathish and Karthick 2020b; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020)). Among these, ((Sathish and Karthick 2020b; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020)) research is considered the best source for this paper. Hybridization of sisal and hemp fiber resulted in a 43% increment in the tensile modulus when compared to neat polylactic acid material.

Previously our team has a rich experience in working on various research projects across multiple disciplines (Venu and Appavu 2021; Gudipaneni et al. 2020; Sivasamy, Venugopal, and Espinoza-González 2020; Sathish et al. 2020; Reddy et al. 2020; Sathish and Karthick 2020a; Benin et al. 2020; Nalini, Selvaraj, and Kumar 2020).Glass and flax fiber appears to offer excessive properties including unique strength and absorbency when mixed with other materials (Quagliarini and Lenci 2010; Taha and Ziegmann 2006). Glass and flax is one of the most durable natural and synthetic fibers, known for its ability to keep its shape. Despite this, glass and flax fiber has a low abrasion resistance and is brittle. As a result, the current research focuses on the Impact Strength of fiber reinforced composites with glass and flax natural fiber and novel Al_2O_3+glass beads nanoparticles as fillers and epoxy and hardener as matrix materials.

MATERIALS AND METHODS

The following research was carried out in the Saveetha Industries, Saveetha School of Engineering (SSE) campus, Saveetha Institute of Medical and Technical Science (SIMATS) Chennai-602105. Because this project involves the manufacturing of metal matrix composites, no ethical approval was necessary. Using ClinCalc software, the sample size is calculated using the G power of 80%(Gardner and Simón 2017). In this research epoxy resin VBR8912 (density 1.16 g/cm^3) and hardener VRB1209 (density 0.98 g/cm^3) are used in the required proportions to create hybrid polymer composites.

In the control group a plain glass/flax fiber hybrid composite is manufactured by a mixture of epoxy and hardener without using filler to it. The epoxy matrix is prepared in 2:1 ratio of epoxy resin and hardener and the matrix mixture is stirred continuously for a few minutes using a mechanical stirrer. A standard mold is used to produce composite plates with required dimensions (300x300x3 mm). A layer of wax is applied evenly to the bottom of the mold, followed by a layer of glass fiber. Using hand layup method the epoxy matrix is then poured and uniformly dispersed, and the process is repeated five times with alternate glass fiber and flax fiber. Using the compression method, the mold is allowed to dry and cure at room temperature for one day. As shown in Fig. 1, 20 test samples were prepared from composite plates in accordance with ASTM-D256 standard.

In the experimental group glass/flax fiber with 4% weight fraction of novel Al_2O_3+glass beads filler hybrid composites were prepared. The epoxy matrix is prepared with epoxy resin, hardener and 4% weight fraction of novel Al_2O_3+glass beads and the mixture is stirred mechanically. Using hand lay up method the hybrid epoxy composite is made in standard mold of 300x300x3 mm. Test samples (n=20) were prepared from the hybrid epoxy composite

and layers along with the epoxy polymer matrix. For material characterisation, the novel hybrid composite samples are well-prepared according to ASTM-D256 standard in two sets (n=20) with and without novel Al_2O_3+glass beads filler materials. The epoxy resin and hardener are combined at 2:1 ratio with 4 wt.% fraction of novel Al_2O_3+glass beads and the matrix mixture is stirred continuously for a few minutes using a mechanical stirrer.

The Flax and glass fiber matt was first cut into 300x300 mm sheets, then a mold with dimensions of 300x300x3 mm was prepared. The epoxy resin was mixed with hardener at a ratio of 2:1 ratio. After the mixture has been prepared, a mylar sheet was placed and wax was added to the sheet, as this aids in the easy removal of the prepared composite plate, a layer of epoxy mixture was uniformly spread over the mylar sheet, and a cut flax and glass fiber mat was placed on the epoxy, another layer of epoxy mixture was poured over the placed fiber mat and evenly applied, and the process was repeated along for a total of 4 layer of flax fiber mat and 3 layer of glass fiber, once done a mylar sheet with wax was placed over it to cover the set up and weight was place over it and left to settle for 24-36 hours. After the 24-36 hour cycle has passed, mylar sheets are to be removed and a composite plate has been formed, the excess epoxy can be cut away to create a Natural laminated epoxy composite plate with dimensions of 300x300x3 mm.

ASTM D256 covers the determination of the resistance of plastics to “standardized” pendulum-type hammers, mounted in “standardized” machines, in breaking standard specimens with one pendulum swing. The standard test for ASTM D256 requires specimens to be made with a milled notch.

The impact resistance of the materials is determined by the Izod impact test. The impact testing machine (IT-30, M/s Fine Manufacturing Industries, India) was used in conjunction with a digital measurement device to determine the material's impact strength for impact analysis. A pivoting arm is raised to a specific height and then released. The arm swings down hitting a notched sample, breaking the specimen. The energy absorbed by the sample is calculated from the height the arm swings to after hitting the sample. A notched sample is generally used to determine impact energy and a computer management device monitors the load at which the sample fails. This impact test was done according to the ASTM-D256 standard.

The significance of the outcomes were analyzed using an independent sample t-test with SPSS-V26 statistical software. To decide the factual idea of the information, the connection between the dependent (Impact strength) and independent (Sample composition) factors is inspected. The study was finished effectively, and the graph was plotted against each example's impact strength and trail numbers.

RESULTS

Glass and flax fiber hybrid polymer composites reinforced with 4 wt.% novel Al_2O_3+glass beads filler are fabricated by the hand layup process. Table 1. shows the mean and standard deviation of test results obtained using SPSS software. Table 2. shows the significance of the findings (impact strength) obtained by Independent t-Test for both sample groups. Figure 1. Geometrical shape of Impact test samples prepared as per ASTM-D256. Figure 2. Shows the composite material without novel Al_2O_3+glass beads fillers result less impact strength. The laminated material with the filler which has shown in Fig. 3. have high impact strength. Figure 4. Impact Testing Machine (IT-30, M/s Fine manufacturing Industries, India) used for Izod impact test. Figure 5. Represent that the with filler is plotted a bar graph and shown in Figure 6. are indicates the without filler test reading is plotted in bar graph was assessed according to ASTM standards. The Izod Impact Strength of hybrid composites fabricated with and without filler are compared and posted in Fig. 7. The Standard deviation error bar is +/- 1SD.

DISCUSSION

In this study, hybrid composite with novel Al_2O_3+glass beads as filler shows better impact strength when compared with composite without novel Al_2O_3+glass beads filler.

The mean value of izod Impact Strength calculated for the control group is found to be 5.1305 J/mm . The maximum and minimum value calculated for the control group is found to be 5.3J/mm and 5 J/mm. The mean value of izod Impact Strength calculated for the test group is found to be 4.4325 J/mm. The maximum and minimum value calculated for the test group is found to be 4.6 J/mm and 4 J/mm. By the referring of (Giasin et al. 2021) we got a similarity of values. The best value is obtained from the similar finding variation of polymer composite materials (PCM) fiberglass-reinforced on impact strength, namely the reinforcement of eight layers, with an impact strength 413,712 MPa. Then the opposing value found in ((Sathish and Karthick 2020b; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020)) of the variation of the polymer composite materials (PCM) fiberglass-reinforced strength on impact strength is the matrix content 2 wt .%, with an impact strength 416,487 MPa.

According to the experimental findings, the increase in impact strength is observed in the polymer composite containing novel Al_2O_3+glass beads powder as a filler compared to those without filler. The novel Al_2O_3+glass beads powder tends to clump together and form agglomerates, resulting in increased impact strength. Figure 7. Shows a comparison of the izod impact strength of the composite without and with filler materials (Sathish and Karthick 2020b; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020)).

The results are compared with each other and shown in Fig. 7. In comparison, it was observed that reinforcement of filler was found to enhance the impact strength of the hybrid composite (Yang, Lue, and Zhang 2010)(Sathish and Karthick 2020b; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020)(Yang, Lue, and Zhang 2010). The novel Al_2O_3+glass beads powder had significantly changed the surface structure and nature of the composites.The addition of novel Al_2O_3+glass beads as a filler increases the izod impact strength of the composites in this study (Quagliarini and Lenci 2010; Taha and Ziegmann 2006)(Sathish and Karthick 2020b; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020)(Anggoro and Kristiana 2015).

Our institution is passionate about high quality evidence based research and has excelled in various fields ((Sathish and Karthick 2020b; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020)(Vijayashree Priyadharsini 2019; Ezhilarasan, Apoorva, and Ashok Vardhan 2019; Ramesh et al. 2018; Mathew et al. 2020; Sridharan et al. 2019; Pc, Marimuthu, and Devadoss 2018; Ramadurai et al. 2019). We hope this study adds to this rich legacy.

The sample fabricated using a hand layup method has a lot of gas porosity and uneven surface finish (Quagliarini and Lenci 2010; Taha and Ziegmann 2006). Study on the mechanical properties of these composites with nano filler and different synthetic and natural fiber orientations along with other fabrication techniques suggested for future work.

CONCLUSION

Within the limitations of the study and the results obtained from the independent t-test, the impact strength of the glass and flax hybrid composite with 4 wt.% novel aluminum oxide and glass beads filler nanoparticles was found to be considerably more by 15.9% than the impact strength of the composite without novel Al_2O_3+glass beads nanoparticles. The study concluded that the composite with novel Al_2O_3+glass beads filler shows greater resistance to impact load when compared to the composite without novel Al_2O_3+glass beads filler. An 15.9% increase in the impact strength of composite was noticed with novel Al_2O_3+glass beads filler composite.

DECLARATION

The authors declare that there is no conflict of interest.

Authors Contribution

The author LV was involved in data collection, analysis and drafting of the manuscript and author MT was involved in conceptualization, data validation and critical review of manuscript.

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TABLES AND FIGURES

Table 1. Mean and Standard Deviation of impact Strength analyzed using SPSS software shown below.

Group Statistics					
Impact strength (J/mm)	**Group**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
	CG	20	5.13	0.13	0.03

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	EG	20	4.42	0.24	0.05

Table 2. Details of Independent sample test results are shown below. The significance of the independent sample test is found to be 0.001.

Independent Samples test									
Impact strength (J/mm)	**LevTest for Equality of Variances**		**t-test for Equality of Means**						
	F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
								Lower	**Upper**
Equal variances assumed	11.92	0.001	11.39	38	0.00	0.71	0.062	0.58	0.83
Equal variances not assumed	-	-	11.39	30.13	0.00	0.71	0.06	0.58	0.83

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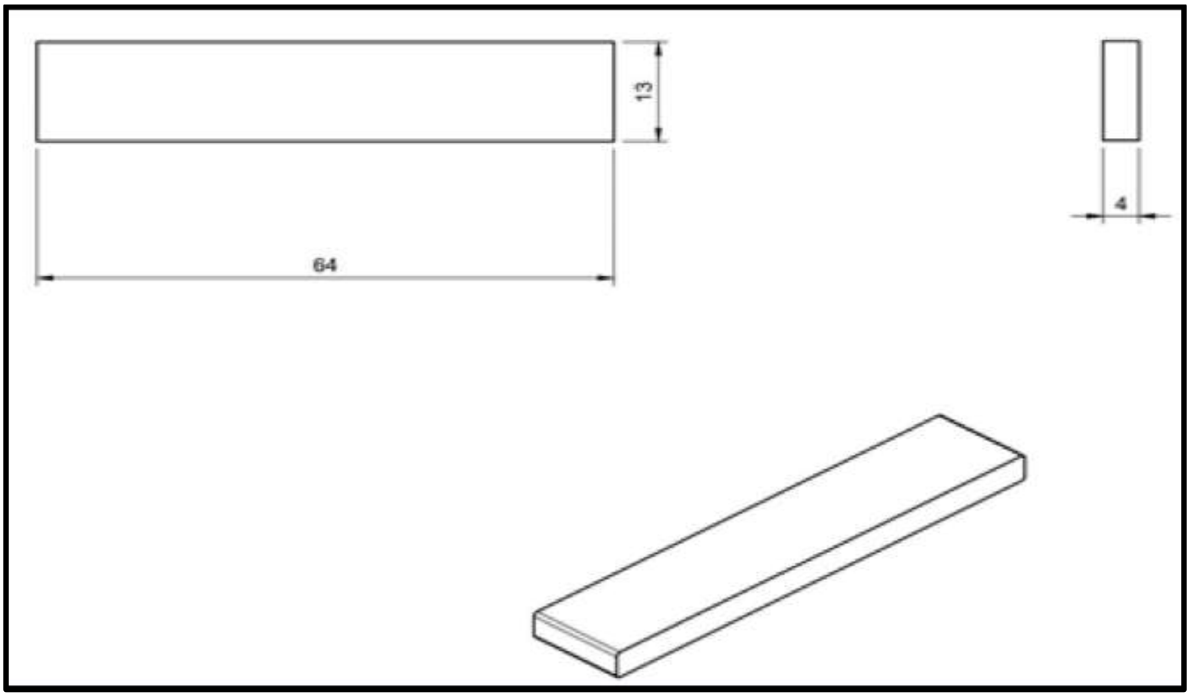

Fig. 1. Geometrical shape of Impact test samples prepared as per ASTM-D256 (all dimensions are in mm).

Fig. 2. Specimens without novel Al_2O_3+glass beads before and after Izod impact testing

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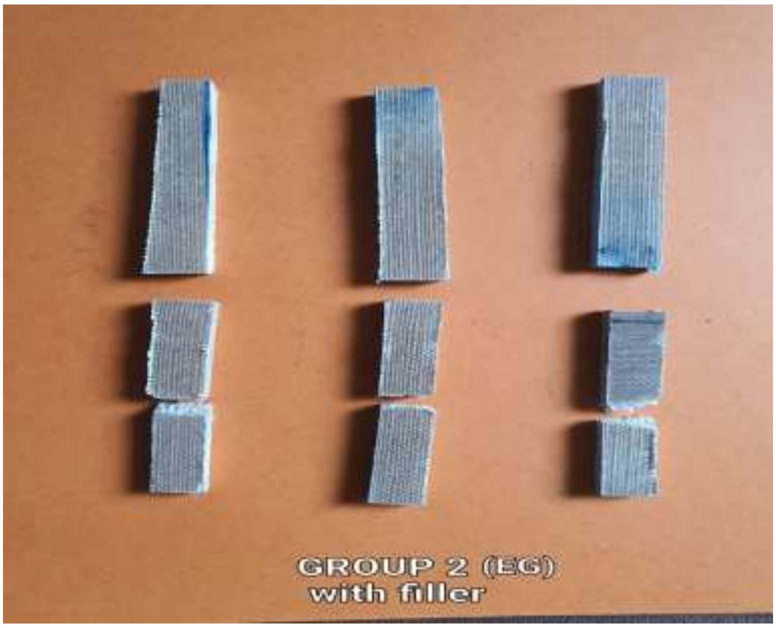

Fig. 3. Specimens 4 wt.% novel Al_2O_3+glass beads before and after Izod impact testing

Fig. 4. Impact Testing Machine (IT-30, M/s Fine manufacturing Industries, India) used for Izod impact test

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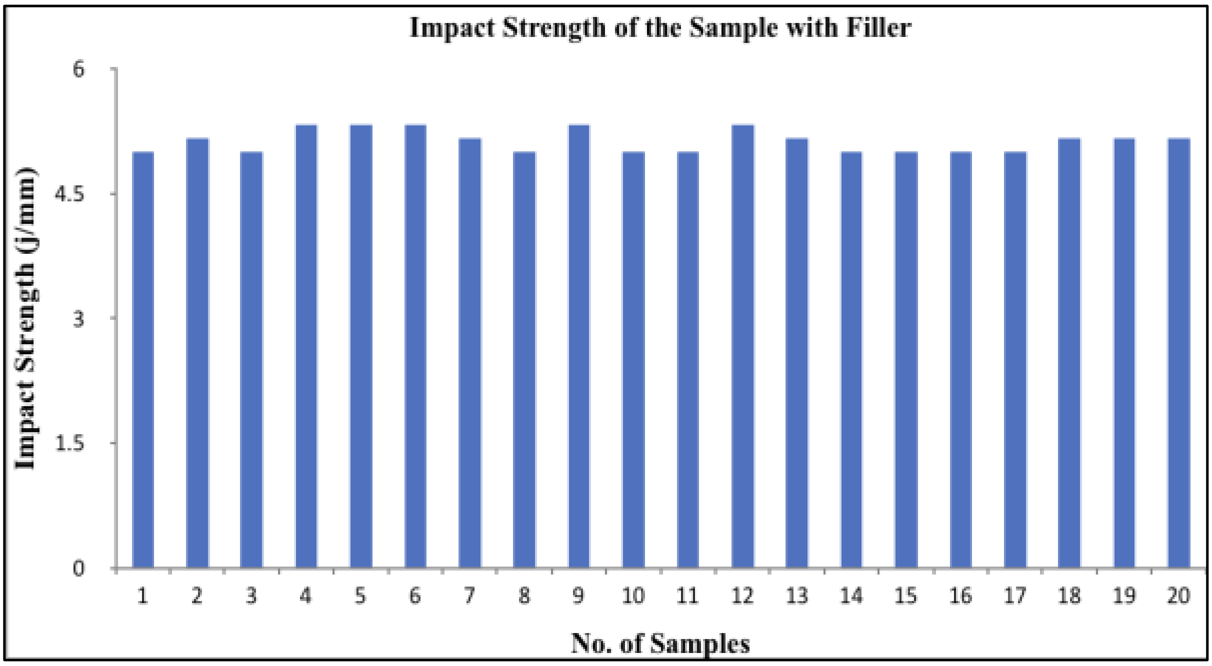

Fig. 5. The samples fabricated with novel Al_2O_3+glass beads filler (independent variable) are tested and the izod impact strength (dependent variable) measured for each sample using standard stipulation are plotted in the above bar graph.

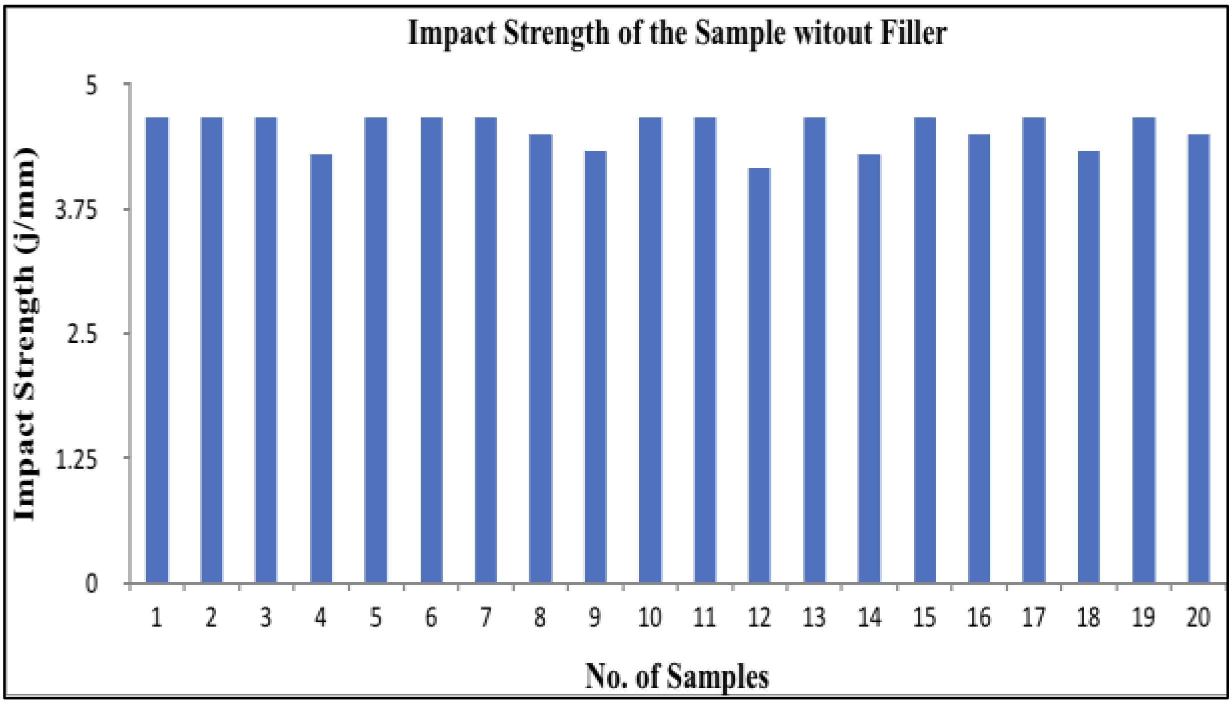

Fig.6. The samples fabricated without novel Al_2O_3+glass beads filler (independent variable) are tested and the izod impact strength (dependent variable) measured for each sample using standard stipulation are plotted in the above bar graph.

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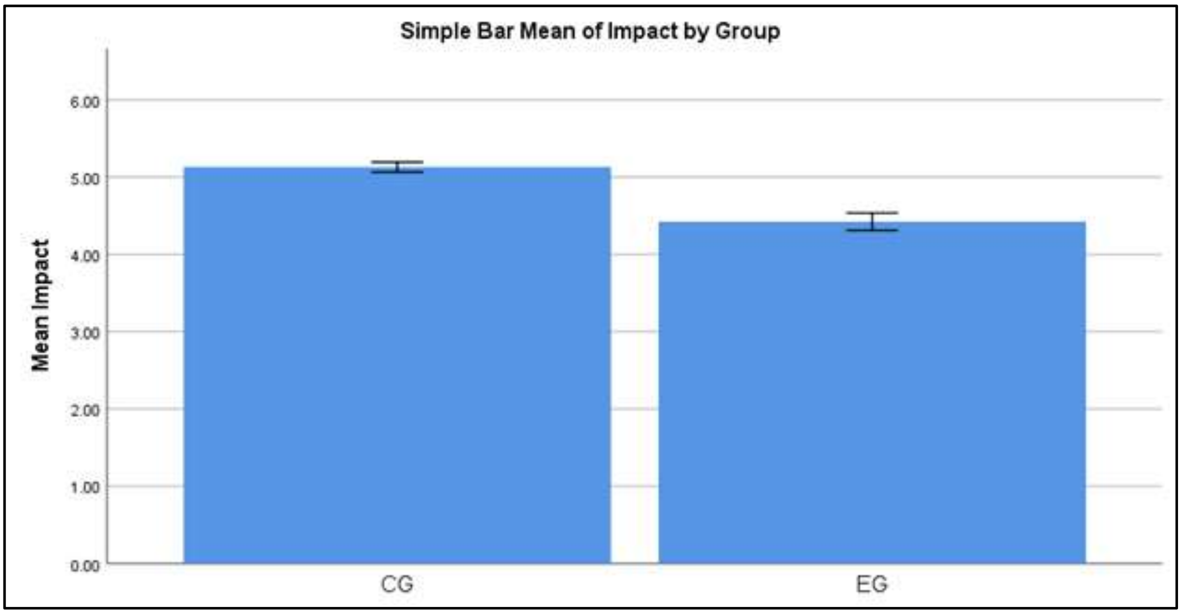

GROUP
Error Bar: 95% Cl
Error Bar: +/- 1 SD

Fig. 7. The Izod Impact Strength of hybrid composites fabricated with and without filler are compared and represented in the bar graph. With a standard deviation of ±1, the mean accuracy of readings obtained. The Izod Impact Strength of the samples fabricated with novel Al_2O_3+glass beads filler (5.13 J/mm) are found to be high compared to the other samples without novel Al_2O_3+glass beads filler (4.42J/mm).