Fabrication, Characterization and Drilling Operation of Natural Fiber Reinforced Hybrid Composite With Filler (Fly-Ash/Graphene)

Pranav Kumar Saraswati, Saritprava Sahoo, Sarada Prasad Parida, Pankaj Charan Jena

Abstract: The aim of the work is to investigate mechanical properties and machining (drilling) behaviour glass-sisal-epoxy hybrid composite (GSEHC) with filler as fly-ash and graphene. Hybrid composites are fabricated by hand lay-up technique using Eglass and sisal as reinforcement fiber and epoxy as binder. Mechanical and physical properties like tensile, bending, impact strength, hardness, density and water absorption percentage are examined. The interfacial properties, internal cracks and internal structure of fractured are observed using Scanning Electron Microscope (SEM). Further drilling operation on the fabricated Hybrid composite was carried by varying the spindle speed as 600 rpm, 900 rpm, 1200 rpm to observe suitable drilling speed to carry the circularity test and delamination factors.

Keywords: composite, delamination, physical property, water absorption, SEM

I. INTRODUCTION

Hybrid composite is an age old field of interest for the researchers in the field of material development. Generally more than two reinforcements or fillers are added to the composites to form hybrid composite. During manufacturing hybrid composite it always tried to use natural fiber as one of the constituent. Now a days use of industrial waste have taken a special class of choice to make waste to wealth with ecological gesture of goodwill to the society. A number works had carried in this regard. A detailed comprehensive literature review on sisal fibre with E-glass fibre based composite material, and different filler reinforced polymer composite material are studied. Ray et al.[1] have fabricated E-glass fibre composites with granite and fly ash as a filler materials in different filler percentage. They have observed that adding of filler elements into the composite increases the erosion resistance property of the composite. Ramesh and Reddy et al. [2] has studied E-glass fibre with natural fibre (sisal/jute) hybrid composite and examine the mechanical properties of composite materials. Microscopic examinations carried out to analyse the material. The outcome of experiments indicated that the combination of natural fibre (sisal fibre) with glass fibre reinforced polymer shown superior performed in flexural properties.

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Ramesh et al. [3] have fabricated glass with natural fibre (sisal & jute fibre) hybrid composite materials in different variation of composition. Mechanical properties calculated and compared such tensile, flexural and impact strength test conducted. Maleki et al.[4]have conducted experiment on drilling of jute fibre reinforced composite. Cutting parameters of composite and analyse the outcome of different type of drill bit on thrust force. And have also calculated delamination factor and surface roughness of the drilled composites.Kumar et al. [5] have developed a composite materials and conducted experimentation at laboratory formechanical characterization of composite (jute and glass fibre).They found that by adding jute fibreincreases the compressive strength of composite. Velmurugan et al. [6] have prepared composite materials E-glass + natural fibre (Sisal & Coir) in different volume variation of filler. Various testing conducted to find out the mechanical properties and they compared the results. They concluded that the addition of 20% sisal and 20% coir fibre gives the optimum value of mechanical properties. Mutalikdesai et al. [7] have focused on categorization of E-glass fibre with epoxy hybrid composites with using different type of filler Fly ash/ Nano clay/ Zinc with the hand lay-up method. Various testing like tensile, Flexural and impact test conducted and compared. It found that addition of nano scale clay with higher fibre combination increase the tensile strength of composite. Kilickap[8] have focused on investigation of the effect of drilling input parameter of glass fibre reinforced polymer composite. They have studied input parameter of drilling operation and the effect of drill bitdimension on delamination and surface roughness. They have observed that lower feed rate gives better surface roughness. Grilo et al. [9] have examined the delamination factors of carbon fibre reinforced polymer composite with using different drill geometries. The effect of three different types of drill geometries and cutting parameter in delamination factor evaluated. Surface roughness of drill surface also studied. Davim et al.[10] have analysed the delamination factor with help of digital image processing to find out the actual diameter of drill of composite materials. And have also examined the delamination when specimen is subjected to stress concentration during machining operation. Hocheng and Tsao[11]have conducted experiment to investigate the delamination factor of composite materials. The drill bit dimension, non-traditional machining, use various type of drill bit and its effect in drilling operation. Hocheng and Tsao[12] have investigated the influence of drill bits in compositematerialsat drilling operation.

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Delamination during drilling operation of composite materials and critical thrust force has evaluated. Delamination has calculated by Ultrasonic scanning. Reddy et al [13]have developed the composite material made up of E-glass + sisal fibre (with/without alkali treatment of sisal fibre). Thehardness, impact strength, frictional. coefficient, and chemical resistanceof compositeshave calculated. They have studied the effect of chemical treatment of fibre. Yuvaraj et al. [14]have focused on studied of Sisal fibre Epoxy Hybrid Composites which is by hand lay out process. They found out the delamination factor, drill tip geometry and feed rate are acting major role for better surface roughness.

Jarukumjorn and Suppakarn[15]have studied the effect of various volume fraction of glass fibre on the fabrication of sisal fibre based composite. Results indicated that combination of glass fibre along with sisal fibre improve the tensile, flexural and impact strength. Additional, adding glass fibre has been increased the thermal properties and water resistance. Devendra and Rangasway[16]havestudied the E glass/epoxy polymer composite with various filler elements to determine the thermal conductivity and thermal co-efficient. they have observed that addition of filler (Al_2O_3& $Mg(OH)_2$) enhance the time ignition. Palanikumar et al. [17] have studied the delamination of GFRP composite. Drilling operation hasbeen done with two different drilled bit. Regression analysis and analysis of variance has also been used. Palanikumar[18] hasexamined the delamination factor and roughness of drilled GFRP composite. Modelling and analysis method has been adopted to find out the confidence level of model. Abrasive glass fibres added in epoxy, as a result hardness and tensile strength increased. Kumar [19]has studied the influence of drilling input parameter like drilled geometry, feed rate and cutting speed in glass fibre/vinyl ester composites. Durao et al. [20] have found the drilled wall roughness and delamination factor. They have observed that drill tip and feed rate influence the factor of delamination. Result indicated that broad drill bit have more delamination factor. Madhavi and Rao [21]have developed a hybrid composite to investigate surface roughness of composite after drilling operation. They have observed that natural fibre made composite have good surface roughness. Cicala et al. [22] have fabricated a hybrid composite in which glass and natural fibres are taken as reinforced material. Result indicated that glass made composite have maximum mechanical properties than natural fibre composite. Dwivedi et al. [23] have made-up of chopped sisal fibre composite to study the mechanical properties and abrasive wear. They have observed that adding filler in composite decrease the wear resistance. Bajpai and Sing [24]have studied the input parameter of drilling such as cutting velocity& feed rate and also investigated the effect of drill specification. Jayobal et al. [25] have made a regression model to optimize the machinability of glass and coir hybrid composite. They have found that the feed rate is important parameter than others. Sain et al. [26] have fabricated a natural fibre composite material to investigate the mechanical properties. They have also done experiment to studies the interface of composite by adding additive in composite. They have observed that low molecular weight affect the interface between fibre and epoxy. Rauison e. al. [27] havefocused on the influence of initiator concentration on composite to increase the mechanical properties of composite materials. Towo and Ansell [28] have fabricated a sisal fibre based composite to investigate the fatigue and dynamic evaluation. They have observed that chemical behaviour of sisal fibre affect the fatigue life of composite materials. Thwe&liao[29] have fabricated a bamboo based natural with glass fibre composite materials to examine the mechanical properties and also checked the durability of composite. Chand &Hashmi[30] have investigated the effect of a sisal fibre at different temperature. Tensile and modulus have been calculated and compared. They have observed that when temperature increased the ductility of epoxy increased. Saha[31] has fabricated a short jute fibre based composite. He has observed that chemical treatment affect the thermal transition temperature. Lopez-Arraiza[32] has developed carbon fibre composite. Drilling operation has been conducted. Various drill geometry has been used to drill the composite materials. Drilling input parameter has also been examined to identify favourable input parameter to get good surface roughness. D'Souza et al[33] has developed a glass fibre based composite with fly-Ash used as filler elements. Experiment has been conducted to analyse the mechanical strength. Fly-Ash added in three different volume fraction 3%, 6% and 9%. They have observed that adding of fly ash decreased the tensile strength. 3% fly ash filler composite have less water absorptivity as compared to others. Xin and Qing [34] have fabricated a sisal fibre based brakes composites. They have observed that 3:4 ratio of epoxy and sisal fibre gives optimum result.

After study of earlier period research papers, it is found that there is no information regarding use of sisal fibre with E glass fibre and Graphene as filler material for fabrication of composite. The mechanical and physical properties may varry after use of Fly ash/Graphene as filler elements.

II. FABRICATION OF COMPOSITE

Hand lay-up process with screw compression method is used to fabricate the hybrid composite material. A mould of 90×900 mm size as shown in figure1 is prepared and used for the purpose. Uniform compression is given for sound surface finish and less void content in the GSEHC. In this work Sisal and E glass fibre are used for fabricating the composite materials. The sisal fibres are obtained from local sources. Epoxy Resin: LAPOX L-12 and the hardener LAPOX K-6 is used. The E glass fiber is in woven form with a density of 450 GSM. Fly ash and graphene is used as the filler material to increase mechanical properties like density, compressive strength and etc. fly ash with different particle sizes are collected by sieving.

Fibre preparation: Sisal leaves are cut from the plant and dipped in water for two days to soften and rotten it for easier pull out of fibers from the leave. The extracted fibre is first sun dried and then dipped in mixture of NaOH (5% wt) and water for five hrs. Then it rinsed thoroughly in water and again dried in sunlight to remove moisture content. the chemical processing of sisal fiber improves bonding between epoxy and fiber in the composite. Then the sisal fibre chopped into 30 mm approximately and mats are made form it manually.

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Processing of filler material: The moisture in filler were removed by heating of fly-ash and graphene in oven at temperature of 100^0 C for 2 hours. The dried filler are then sieved in order to get particle size of 105µm before composite fabricated.

Total five layer of fiber layers weighing 60% of total weight of the composite with 5% of filler material is taken to make the specimens. Five test samples with various compositions are prepared

Table-I. Composition Of Test Samples

Sl no.	Name	EGlass (%wt)	Sisal (%wt)	Graphene (%wt)	Flyash (%wt)
1	P1	30	30	5	__
2	P2	30	30	__	5
3	P3	60	___	5	__
4	P4	60	___	___	5
5	P5	60	___	__	__

Figure1. GSEHC With Filler In Compression Mould

Figure2.Test Specimens From GSEHC With Filler In Compression Mould

III. MATERIAL CHARACTERIZATION

Tensile test: To prepare the test specimens the edges of the specimen are filed and for surface are finished by using sand papers. Tensile test Specimens are prepared according to UTM standard and the tests were carried at an ambient temperature of 37° C . The specimen fitted in the UTM and applied load until fracture and break. The elongation due to load is recorded. This experiment is repeated for 3 times and takes average value for presentation.

Flexural strength: The specimens are prepared according to UTM standard. The 3 point bending is common for checking flexural strength of materials. The specimen placed into the UTM UTE-20-HGFL and applying load until fracture and breaks.

Impact Test: The test specimen prepared as per to the essential specification of impact testing machine AIT-300D. The test specimen placed in the test machine and releases the pendulum and specimen fractured due to impact force. Outcome of this test give the value of energy needed to breaks the materials and also measure the toughness of the materials.

Micro hardness test: Hardness is a physical property of materials. In the present works, Vickers hardness test method is adopted. It is also called Micro hardness. A light range of load that is 20 gm to 2 kg is applied to find the hardness value. In this work 0.025 kgf load is applied to find the impression on composite materials. An optical measurement system is installed on Vickers hardness machine which is measure the dimension of impression areas. Dwell time 15 second to compression

Drilling of composite beam: Fibre reinforced composite are used broadly for their mechanical superior properties and advantage for application in automobile, Railways, domestic and road Bus. Generally, composite are fabricated to proper shape and size but some time need additional machining operation like drilling. Anyway, the cutting may damage the work materials surface. The composite specimen is drilled without any coolant by H.S.S twist drill bit of diameter of 12 mm with the point angle $125^{0.}$ Parameters like circularity, hole diameter, surface roughness and delamination factor was investigated. Circularity error was found out by using SPECTRA ACCURA CCM machine. The drilled work piece is placed on CCM table and a ruby probe (2mm diameter) is taken at six different points on the internal wall of drilled hole. The value of circularity is evaluated directly from CCM. Surface roughness is measured by the portable Roughness Testing profile meter Surface SJ-210 – series 178. The readings were taken at six different locations of the machined component & their average value is plotted for Ra value.

Measurement of delamination: Drilling is a general machining action for fastening joining of parts made of composite materials. During drilling operation delamination occur [J. Babu, T. Sunny, N. Paul et al]. Rejection rate of drilled specimen in assembly operation is very high. So, delamination can decrease the acceptance of the finished parts. As drilling operation started first layer of fibre being taken up with drill flute is peel-up mechanism. the fibre is compressed under the drill and when it comes to the bottom layer it will stretch out the laminae from the hole for which delamination factor of the composite will be increased as well as decrease in surface roughness known as push out delaiation.

IV. RESULT AND DISCUSSION

Tensile properties: The sisal fibre and glass fibre based composite beam is prepared for tensile test with different composition of materials. Tensile tested is conducted with the help of universal testing machine UTE-20-HGFL.

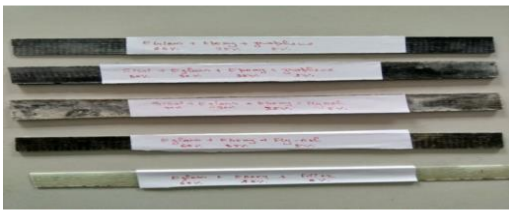

Fig.3(a). Specimen Of Hybrid Composite Beam Before Test

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Fig.3(b). Specimen Of Hybrid Composite Beam After Test

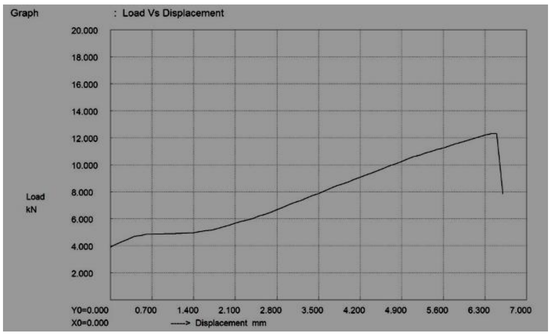

Fig. 4. (a) Load Vs. Displacement Graph

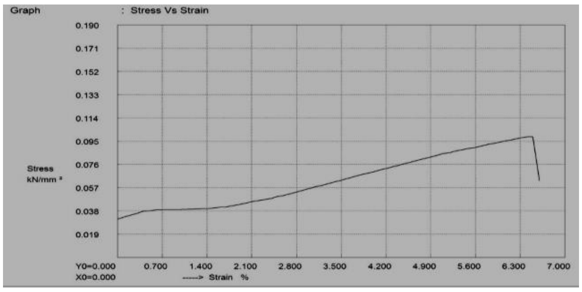

Fig. 4. (b) Stress And Strain Curve

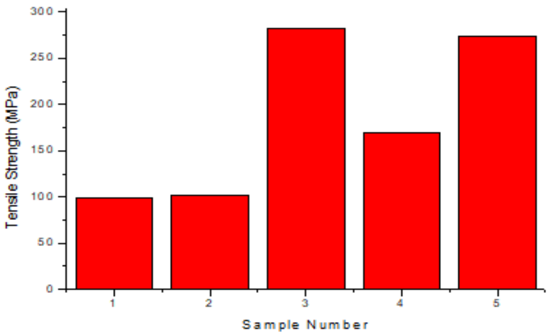

Fig. 5: Tensile Strength Of Various Composite Sample

Flexural Strength : Flexural test is done at Universal Testing Machine UTE-20-HGFL. The test results are enlisted in table. Stress Vs.strain curve and Load Vs.. Displacement curve obtained from the test for sample 4 is shown in figure 6. The flexural strength of the GSEHC specimens with E-glass, Sisal, Epoxy and Fly ash/Graphene as is 41.24MPa and 48.4MPa respectively. When sisal fiber is replaced in place of e glass flexural strength is reduced as demonstrated from experimental result depicted in table 2. Also it is found that addition of filler material reduces the flexural strength

Table -II: Flexural Strength Of Composite

Composite	flexural strength (MPa)	Flexural load (KN	Displacement (mm)
P1	41.24	4.64	11
P2	48.40	4.84	10.8
P3	96.04	4.61	21
P4	78.5	4.71	15.7
P5	122.2	4.40	31.30

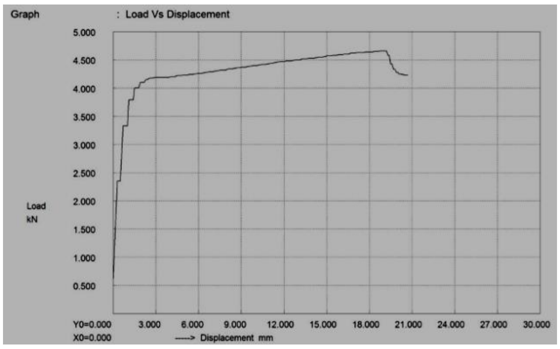

Fig.6 (a) Stress Vs. strain curve

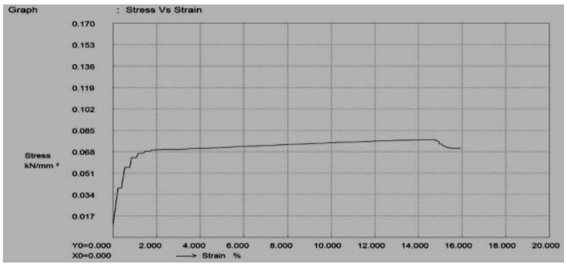

Fig.6 (b) Load Vs. Displacement

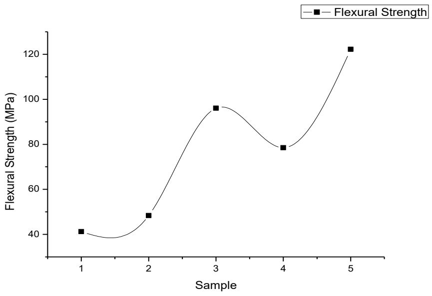

Figure 7: Flexural Strength Vs. Maximum Load

Impact test Result: The test specimens are prepared according to the ASTM standard of machine AIT-300D. The specimen placed in the test machine and the weight is released and the energy needed to breaks specimen is recorded as measure of the toughness of the materials is displayed on screen. Table 3 indicate the impact test results of the specimens

Table-III: Impact Strength Of Composite

Sl no	Impact Energy (Joule)	Impact Strength (J/cm^2)
1	2.9	7.3
2	2.5	6.3
3	3.1	15.5
4	4.1	10.2
5	1.7	8.7

Micro hardness Test: The micro hardness test Results indicate that hardness value of hybrid composite made of E glass and sisal with graphene as filler have highest hardness value among all composites specimen. It also found that adding fly ash increases the hardness of composite materials.

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Table-IV: Micro Hardness Results

Sl no	Hardness Value
1	5.7 HV
2	10.7 HV
3	14.1 HV
4	4.3 HV
5	7.4 HV

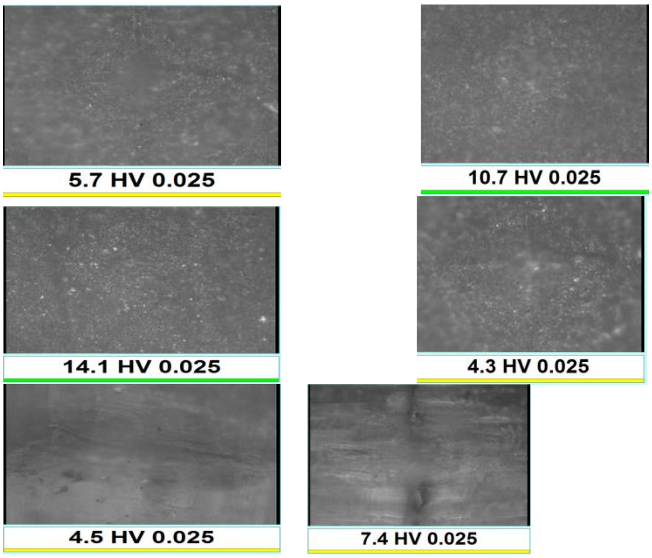

Figure8: Microscopic View Of Specimen After Indentation

Water absorptivity : Water absorption of five composites is conducted as per ASTM D570. Five composites specimen were deep in distilled water at ambient temperature for 7 days. This experiment is divided into four segments that is 3 day, 5 day, 6 days and 7days. In every segment data is recorded and converted it in percentage as per the formula which is given in equation 5.1. Following is the graph of water absorption of composite materials.

Mathematically,

$$\text{Water absorption } \% = \frac{(\text{Wet weight} - \text{dried weight})}{\text{dry weight}} \times 100$$

Results indicate that the water absorption capacity of sample 4 is very less than others. Sample-1 has maximum water absorptive is very high. The reason behind this is that sisal fibre have higher tendency to absorb the water.

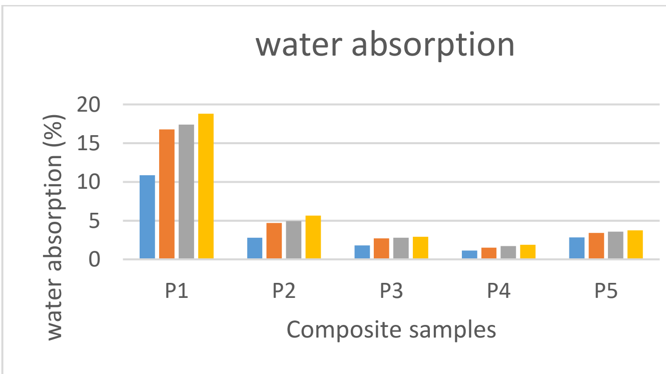

Figure 9: Water Absorption Of Specimens

Scanning Electron Microscopy Analysis: The hybrid composite specimens are examined by the help of scanning electron microscopy (SEM). The SEM images of composite samples after tensile test are presented in figure 10.

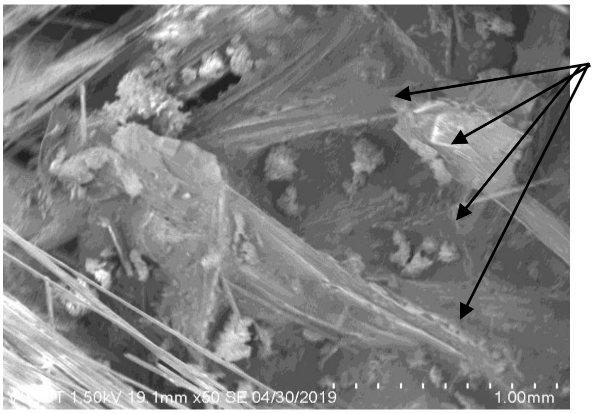

Figure 10: Position of sisal fibre in composite P1after tensile test

Delamination

Table 5.5: Delamination factor of composites

Composite	Spindle speed (RPM)	Circularity	D_{max} mm	Delamination factor
P1	700	0.2574	12.4244	1.035
P1	900	0.4314	13.0744	1.089
P1	1200	0.5928	12.3952	1.032
P2	700	0.1647	12.6570	1.054
P2	900	0.0408	12.6341	1.052
P2	1200	0.3181	13.4025	1.116
P3	700	0.3171	12.6822	1.056
P3	900	0.0852	12.7598	1.063
P3	1200	0.4899	13.2218	1.101
P4	700	0.3282	12.5508	1.01
P4	900	0.0865	12.6899	1.057
P4	1200	0.0654	12.6938	1.057
P5	700	0.2232	12.7077	1.058
P5	900	0.4378	12.5391	1.044
P5	1200	0.5224	13.0391	1.086

Effect of spindle speed

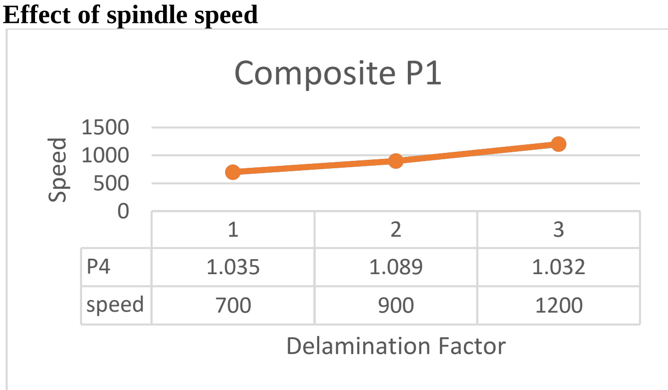

Fig. 11: Speed Vs. Delamination Factor Curve

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V. CONCLUSIONS

It is found that GSEHC with E-glass (60 wt. %) , 0% sisal and Graphene (5 wt. %) as a filler (P3) have maximum tensile strength about 282MPa among all composites. Results of flexural test indicates that GSEHC with E glass fibre (60wt. %) without any

filler have highest (122 MPa) flexural strength. It is also found that addition of filler material decrease the flexural strength. Addition of graphene in composite increases the impact strength and hardness value. E glass fibre with 5% filler reinforced polymer give 15.5J/cm^2 impact 14.1 HV respectively. It is found that in present work, addition of sisal fibre increase the water absorptivity of composite.

In present work, drilling operation is done at three spindle speed it is 700, 900, 1200 rpm. Among these rpms composite drilled at 700 rpm gives circularity of 0.2574.Among the five variant of composite, E glass fibre (60%) with 5% graphene as filler material reinforced polymer have suitable tensile, flexural, impact, hardness and circularity.

REFERENCES

1. S. Ray, A. K. Rout, and A. K. Sahoo, "Development and characterization of glass/polyester composites filled with industrial wastes using statistical techniques," Indian J. Eng. Mater. Sci., vol. 25, no. 2, pp. 169–182, 2018.
2. M. Ramesh, K. Palanikumar, and K. H. Reddy, "Comparative Evaluation on Properties of Hybrid Glass Fiber- Sisal / Jute Reinforced Epoxy Composites," Procedia Eng., vol. 51, no. NUiCONE 2012, pp. 745–750, 2013.
3. K. Palanikumar, B. Latha, V. S. Senthilkumar, and J. P. Davim, "Analysis on drilling of glass fiber-reinforced polymer (GFRP) composites using grey relational analysis," Mater. Manuf. Process., vol. 27, no. 3, pp. 297–305, 2012.
4. H. Rezghi Maleki, M. Hamedi, M. Kubouchi, and Y. Arao, "Experimental study on drilling of jute fiber reinforced polymer composites," J. Compos. Mater., vol. 53, no. 3, pp. 283–295, 2019.
5. A. Kumar and A. Srivastava, "Preparation and Mechanical Properties of Jute Fiber Reinforced Epoxy Composites," Ind. Eng. Manag., vol. 06, no. 04, pp. 4–7, 2018.
6. T. Nadu and T. Nadu, "Mechanical Testing of Hybrid Composite Material (Sisal and Coir)," vol. 4, no. 7, pp. 1–6, 2014.
7. S. Mutalikdesai, A. Hadapad, S. Patole, and G. Hatti, "Fabrication and Mechanical Characterization of Glass fibre reinforced Epoxy Hybrid Composites using Fly ash/Nano clay/Zinc oxide as filler," IOP Conf. Ser. Mater. Sci. Eng., vol. 376, no. 1, pp. 1–7, 2018.
8. E. Kilickap, "Investigation into the effect of drilling parameters on delamination in drilling GFRP," J. Reinf. Plast. Compos., vol. 29, no. 23, pp. 3498–3503, 2010.
9. T. J. Grilo, R. M. F. Paulo, C. R. M. Silva, and J. P. Davim, "Experimental delamination analyses of CFRPs using different drill geometries," Compos. Part B Eng., vol. 45, no. 1, pp. 1344–1350, 2013.
10. J. P. Davim, J. C. Rubio, and A. M. Abrao, "A novel approach based on digital image analysis to evaluate the delamination factor after drilling composite laminates," Compos. Sci. Technol., vol. 67, no. 9, pp. 1939–1945, 2007.
11. H. Hocheng and C. C. Tsao, "The path towards delamination-free drilling of composite materials," J. Mater. Process. Technol., vol. 167, no. 2–3, pp. 251–264, 2005.
12. H. Hocheng and C. C. Tsao, "Effects of special drill bits on drilling-induced delamination of composite materials," Int. J. Mach. Tools Manuf., vol. 46, no. 12–13, pp. 1403–1416, 2006.
13. M. Ashok Kumar, G. Ramachandra Reddy, Y. Siva Bharathi, S. Venkata Naidu, and V. Naga Prasad Naidu, "Frictional coefficient, hardness, impact strength, and chemical resistance of reinforced sisal-glass fiber epoxy hybrid composites," J. Compos. Mater., vol. 44, no. 26, pp. 3195–3202, 2010.
14. G. Yuvaraj, B. Vijaya Ramnath, A. Abinash, B. Srivasan, and R. Vikas Nair, "Investigation of Mechanical Behaviour of Sisal Epoxy Hybrid Composites," Indian J. Sci. Technol., vol. 9, no. 34, 2016.
15. K. Jarukumjorn and N. Suppakarn, "Effect of glass fiber hybridization on properties of sisal fiber-polypropylene composites," Compos. Part B Eng., vol. 40, no. 7, pp. 623–627, 2009.
16. K. Devendra and T. Rangaswamy, "Evaluation of Thermal Properties of E-Glass/ Epoxy Composites Filled By Different Filler Materials," Int. J. Comput. Eng. Res., vol. 25, no. 5, pp. 2250–3005, 2012.
17. K. Palanikumar, S. Prakash, and K. Shanmugam, "Evaluation of delamination in drilling GFRP composites," Mater. Manuf. Process., vol. 23, no. 8, pp. 858–864, 2008.
18. K. Palanikumar, "Modeling and analysis of delamination factor and surface roughness in drilling GFRP composites," Mater. Manuf. Process., vol. 25, no. 10, pp. 1059–1067, 2010.
19. S. Kumar, S. R. Chauhan, P. K. Rakesh, I. Singh, and J. P. Davim, "Drilling of glass fiber/vinyl ester composites with fillers," Mater. Manuf. Process., vol. 27, no. 3, pp. 314–319, 2012.
20. L. M. P. Durão, D. J. S. Gonçalves, J. M. R. S. Tavares, V. H. C. de Albuquerque, A. Aguiar Vieira, and A. Torres Marques, "Drilling tool geometry evaluation for reinforced composite laminates," Compos. Struct., vol. 92, no. 7, pp. 1545–1550, 2010.
21. V. R. Madhavi and S. S. S. Rao, "Preparing , Studying and Drilling the Composite Materials with different Orientation of Fibers," pp. 48–55, 2017.
22. G. Cicala, G. Cristaldi, G. Recca, G. Ziegmann, A. El-Sabbagh, and M. Dickert, "Properties and performances of various hybrid glass/natural fibre composites for curved pipes," Mater. Des., vol. 30, no. 7, pp. 2538–2542, 2009.
23. U. K. Dwivedi and N. Chand, "Influence of MA-g-PP on abrasive wear behaviour of chopped sisal fibre reinforced polypropylene composites," J. Mater. Process. Technol., vol. 209, no. 12–13, pp. 5371–5375, 2009.
24. P. K. Bajpai and I. Singh, "Drilling behavior of sisal fiber-reinforced polypropylene composite laminates," J. Reinf. Plast. Compos., vol. 32, no. 20, pp. 1569–1576, 2013.
25. S. Jayabal, U. Natarajan, and U. Sekar, "Regression modeling and optimization of machinability behavior of glass-coir-polyester hybrid composite using factorial design methodology," Int. J. Adv. Manuf. Technol., vol. 55, no. 1–4, pp. 263–273, 2011.
26. M. Sain, P. Suhara, S. Law, and A. Bouilloux, "Interface modification and mechanical properties of natural fiber-polyolefin composite products," J. Reinf. Plast. Compos., vol. 24, no. 2, pp. 121–130, 2005.
27. K. Debnath, I. Singh, and A. Dvivedi, "Drilling characteristics of sisal fiber-reinforced epoxy and polypropylene composites," Mater. Manuf. Process., vol. 29, no. 11–12, pp. 1401–1409, 2014.
28. A. N. Towo and M. P. Ansell, "Fatigue evaluation and dynamic mechanical thermal analysis of sisal fibre-thermosetting resin composites," Compos. Sci. Technol., vol. 68, no. 3–4, pp. 925–932, 2008.
29. M. M. Thwe and K. Liao, "Durability of bamboo-glass fiber reinforced polymer matrix hybrid composites," Compos. Sci. Technol., vol. 63, no. 3–4, pp. 375–387, 2003.
30. N. Chand and S. A. R. Hashmi, "Mechanical properties of sisal fibre at elevated temperatures," J. Mater. Sci., vol. 28, no. 24, pp. 6724–6728, 1993.
31. A. K. Saha, S. Das, D. Bhatta, and B. C. Mitra, "Study of Jute Fiber Reinforced Polyester Composites by Dynamic Mechanical Analysis," J. Appl. Polym. Sci., vol. 71, no. 9, pp. 1505–1513, 1999.
32. A. Lopez-Arraiza, I. Amenabar, A. Agirregomezkorta, M. Sarrionandia, and J. Aurrekoetxea, "Experimental analysis of drilling damage in carbon-fiber reinforced thermoplastic laminates manufactured by resin transfer molding," J. Compos. Mater., vol. 46, no. 6, pp. 717–725, 2012.
33. R. Obed D'Souza, Y. P. Shettigar, D. Prajwal Byndoor, S. S. Sudhakar, N. Ahmed, and R. Shetty, "Experimental Analysis on the Mechanical Properties of Glass-Epoxy composite with Fly ash as a filler material," IOP Conf. Ser. Mater. Sci. Eng., vol. 376, no. 1, pp. 0–6, 2018.
34. X. Xin, C. G. Xu, and L. F. Qing, "Friction properties of sisal fibre reinforced resin brake composites," Wear, vol. 262, no. 5–6, pp. 736–741, 2007.

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