Original Article

Experimental Investigation of Drilling Characteristics of Novel Glass Fiber Composite Reinforced with Aluminium Wire Mesh

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Abstract

Aim: This study aims to fabricate and evaluate the drilling characteristics and cylindricity tolerance of novel composites reinforced with aluminium wire mesh and plain glass fiber composite material. **Materials and Methods:** This study works on the fabrication of novel composite materials, these composite materials were prepared using glass fiber and kevlar fiber reinforced with aluminium mesh. The composite material reinforced with wire mesh was taken as an experimental group with a sample size of 20 (N=20). The plain glass fiber composite material is taken as a control group with a sample size of 20 (N=20). The composite sample size was calculated by keeping 80% of G-power. Hand Layup Technique is used for fabricating both groups of composite materials. SPSS software is used for statistical analysis. **Result:** The mean values obtained by the control group and experimental group were 80.31% and 70.65% respectively. Glass fiber composite reinforced with wire mesh shows better drilling characteristics and also a decrease in cylindricity tolerance, the significant value obtained is $p=0.025$ ($P<0.05$). There is a significant difference between the groups. **Conclusion:** Within the limits of the study, glass fiber composite reinforced with aluminium wire mesh shows a 18% decrease in cylindricity tolerance during dilling. So the reinforced composites can be used in many automobile and marine applications.

Keywords: Glass Fiber, Kevlar Fiber, Aluminium Mesh, Epoxy Resin (LY556), Hardener (HY951), Novel composites, SPSS Tool, ImageJ software.

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INTRODUCTION

Composite materials are the most extensively used materials in the present world, in most cases, composite materials are preferred over traditional materials because of their properties. Glass fiber-reinforced polymeric (GFRP) composites were most commonly used in the manufacturing of composite material and they are very cost-effective. Glass fiber materials are stronger than many metals and can be designed into complicated shapes (Sivasaravanan, Raja, and Manikandan 2014). The main objective of this study is to improve the drilling characteristics and cylindricity tolerance of glass fiber composite reinforced with aluminium wire mesh. The reinforced composite material has better drilling characteristics than the plain glass fiber. The inclusion of aluminium wire mesh increases the strength of the composite material, the cylindricity tolerance is found by drilling the fabricated composite material in a Vertical CNC machine using an HSS drill bit (Lassila et al. 2018). Glass fiber reinforced composites are used in a wide range of applications such as marine, aerospace, automobile, electronic components, and defense-related special areas (Czech et al. 2021). The composites reinforced with aluminium wire mesh can be used as constructional materials (Kulkarni 2014 et al. 2014).
The total number of research papers published closely related to this research work is 391 in google scholar and 236 in science direct in the past five years. Glass fiber-reinforced composite materials are the most widely used and most affordable fiber-reinforced composite materials. Drilling is one of the most important machining operations carried on reinforced composite material (Prakash et al. 2019), the stiffness of the glass fiber is low as compared to other reinforcement fibers, but glass fiber poses high strength with low density, and most of all at a very reasonable cost. Glass fiber will be used as a major reinforcement fiber in future also for making composite materials. The fabricated glass fiber composite samples are drilled in CNC machines. After drilling both group samples hole delamination, cylindricity tolerance, and drilling parameters are analyzed (Abdullah and Sapuan

2019). During the drilling of composite material, numerous damages like bore pullout, delamination, and cylindricity tolerance will happen (Shao et al. 2021). The feed rate is one of the most critical parameters during drilling of the novel composite materials and the feed rate should be given very carefully to avoid damage. This study indicates that the delamination increases with the increase of feed rate and the delamination can be decreased by increasing the spindle speed (Rajamurugan, Shanmugam, and Palanikumar 2013). The closely related research to this research work is (Shao et al. 2021) in this research it is concluded that feed rate is the most important parameter during the drilling of Novel composites.

Our team has extensive knowledge and research experience that has translate into high quality publications(Bhansali et al. 2021; Jayanth et al. 2021; Sudhakar, Ravel, and Perumal 2021; Sathiyamoorthi et al. 2021; Deepanraj et al. 2021; Raju et al. 2021; Arun Prakash et al. 2020; Kamath et al. 2020; Shanmugam et al. 2021; Rajasekaran et al. 2020; Adhinarayanan et al. 2020; Rajesh et al. 2020; Aurtherson et al. 2021). The rapid growth in the usage of composite materials motivated us to pursue this research work. This study was about the glass fiber composite reinforced with aluminium wire mesh and plain glass fiber composite. There is no much research on mechanical behaviour of glass fibre laminate reinforced with wire mesh. The aim of this study is about the drilling characteristics of glass fiber composite reinforced with aluminium wire mesh and they were compared with plain glass fiber composite.

MATERIALS AND METHODS

This experimental research study was conducted in Mechanical Workshop in Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai. The ethical approval for the study was non-obligatory as the study did not involve the usage of human samples. This research study consists of two group samples namely the control group and the experimental group, both groups consist of 40 samples (20 samples for the control group and 20 samples from the experimental group), the control group which involves plain glass fiber composite embedded with epoxy resin and the experimental group in which the glass fiber is reinforced with aluminium wire mesh, Hand lay-up technique is used for the fabrication process. This study explains in detail the methods of fabrication and their application with brief results and discussion. The number of samples was calculated by using the G-power calculator from cliniCalc.com by keeping alpha value 0.05 and power value 80%, by referring to the previous paper mean value and standard deviation values were taken for example calculations (Kang 2021).

The novel composites were made up of glass fiber reinforced with aluminium wire mesh. The glass fibre is trimmed to the size of 30×30 cm for two layers and the aluminum mesh is also trimmed to the size of 30 × 30 cm for one layer. The epoxy resin (LY556) is mixed with Hardener (HY951) with a mixture ratio of 10:1. Initially, a mylar sheet is placed on the work table and an epoxy hardener mixture is applied equally all over the mylar sheet and kevlar fiber is used as a facing material and is placed on top of the glass fiber to increase the strength of the material, glass fiber is placed between the kevlar fiber and the aluminium wire mesh is placed in the middle of the glass fiber epoxy resin is applied for layer by layer. The laminated composite material is set to cool for about 24 hours under high pressure to get hard. After 24 hours remove the reinforced composite from the pressure and remove mylar sheets from the composite.

Similarly, the sample preparation of the control group involves plain glass fiber embeds with epoxy resin taken as a control group. For this research plain glass fiber of the specification of 1.5 mm thickness and 2.44(g/cm^3)of density is taken. The epoxy resin (LY556) and hardener (HY951) were taken in the 10:1 ratio and mixed very well. Initially, the sample is fabricated with 30 *30 cm then it is trimmed to 10 *10 cm for the machining process. A mylar sheet is placed on the plain surface, and resin is applied on the sheet, kevlar fiber is placed on the mylar sheet as a facing material and glass fiber is placed on the kevlar fiber 2 layers of each fiber is placed for lamination, place a mylar sheet on the fibers and apply some weight on the polymer. Leave the fabricated samples for about 24hrs to let the resin dry and after 24hrs remove the weight on the samples and separate the mylar sheet from the fabricated sample.

The composite material samples of both the experimental and control group are trimmed to 100*100 cm as per the requirements and the samples are placed over the worktable of the CNC drilling machine and 20 holes are drilled in each of the two samples using an 8mm diameter HSS (High-Speed Steel) drill bit under given feed conditions Fig. 1 shows the holes drilled in the plain kevlar fiber sample and Fig. 2 shows the holes drilled in the reinforced novel composites.

The hole quality assessment to find the cylindricity tolerance in the drilling of the glass fiber composite material is done manually by taking individual pictures of the drilled holes of both experimental group samples and control group samples under LED lights using a camera and the images of both samples are scanned in ImageJ software to find out they are damaged around the drilled holes by using freehand sketch module available in the ImageJ software to find the experimental drilled hole area and compare it with the theoretical drilled hole area based on the diameter of the drill bit used and this process is repeated for all the 20 drilled holes of both experimental and control groups.

A vertical CNC machine is used for drilling the both group samples. In Fig. 3 the drilling setup in the CNC machine is shown. ImageJ software is used to calculate the damaged area around the drilled holes of both group samples. The data obtained from the ImageJ software of both samples are compared, and cylindricity tolerance is obtained.

Statistical Analysis

SPSS statistical software version 21 is used for analyzing the data obtained from ImageJ software. In SPSS software both experimental and control groups samples are entered for analysis. The two group samples are taken as dependent variables. A G-graph and Descriptive values are obtained from the analysis. The G-graph was obtained from the SPSS software (Stehlik-Barry and Babinec 2017).

RESULTS

The data obtained from the SPSS statistical analysis shows that novel composites reinforced with aluminum show better hole quality and a decrease in cylindricity tolerance during the drilling of composite material. The cylindricity tolerance of the experimental group is lower than the control group. The cylindricity tolerance of the experimental group is 10% lower than the control group. The inclusion of aluminium wire mesh reduced the delamination of composite material and also increased strength, mechanical properties.

The G-graph shows the cylindricity tolerance difference between the glass-reinforced with aluminium wire mesh and plain glass fiber and it is represented in Fig 4. In this study, we observed that the cylindricity tolerance of glass fiber reinforced with aluminium wire mesh decreased than the plain glass fiber. The mean value of cylindricity tolerance of plain glass fiber composite and reinforced composite material is 80.31% and 70.651%, The mean values of both samples are shown in Table. 1. The significant value of cylindricity tolerance is obtained as $P=0.025$ ($P<0.05$) and the significant value is represented in Table. 2. The results were obtained when sample values are subjected to the independent sample T-test analysis using SPSS v. 26 Statistical software. The mean bar graph shows cylindricity tolerance obtained for plain glass fiber and Glass fiber reinforced with aluminium wire mesh. The mean cylindricity tolerance of plain glass fiber is higher than glass fiber reinforced with aluminium wire mesh. Mean cylindricity tolerance (mm^2) ± 1 SD. The average values of both samples which are obtained from The ImageJ software is represented in Table. 3.

DISCUSSION

In this research study we observed that the novel reinforced composite sample has better mechanical properties than the plain composite sample, the significance value of the novel composite sample is $P=0.025$ ($P<0.05$), the obtained results shows that the mean value and standard deviation for cylindricity tolerance of glass fiber reinforced composite is 70.65 and 0.7276 respectively, The mean value and standard deviation of plain glass fiber composite is 80.31 and 0.28. This study is about novel composite materials, developed and tested in an experimental study (Novel Composite Materials). Composite materials are weightless as compared to the other conventional materials, for example, reinforced glass-fiber can be up to five times stronger than 1020 grade steel and only one-fifth of the weight, making it perfect for structural purposes. According to the findings, GFRP is less in weight and can be easily manufactured in almost any shape, allowing great design flexibility (Amir et al. 2019). The delamination behaviour and hole quality of the composite samples are investigated in the present study. According to the analysis of variance data, drill bit type and feed have stronger impacts on thrust force, reduction of thrust force is necessary to minimize delamination (Palanikumar et al. 2016). The Mode of drilling, cutting speed, and feed were found to be significant parameters that affect the drilling-induced damage (Joshi, Singh, and Singh 2014) . The feed rate has a considerable impact on the delamination factors and cylindricity tolerance (Jia et al. 2016). There are no contradictions related to this research work.

Some of the factors affecting the results of the novel composite materials were the mixing ratio of epoxy resin and hardener; the exact ratio of the mixture of resin and hardener is 10:1. The air gaps between the layers occur due to the irregular rolling process between the layers, this affects the results of the composite samples, and the quality of the material will affect the result of the final product.This project fabrication process required skilled labor and the hand layup technique is used for preparing the novel composite material. The hand layup technique is a time taking process. This technique is not applicable for bulk production. No protection against moisture, structural strength will decrease; there will be no fire protection. Delamination occurs between the layers and moreover improper bonding between the fiber and wire mesh.(Mugahed Amran et al. 2020). This work will be extended in the future by using natural fibers which are environmentally friendly like Jute fiber, Kenaf fibers, etc. Different structural layers can also be tried to check the mechanical properties of the composite material.

CONCLUSION

Within the limits of this study, the novel composites reinforced with aluminium mesh composite material shows a 18% decrease in the cylindrical tolerance compared with plain glass fiber polymer. It significantly shows that the addition of aluminium wire mesh to the plain glass fiber reinforced polymer improves the drilling characteristics of glass fiber and reduces the fiber pullout and delamination during the composite drilling.

DECLARATION

Conflicts of Interest
The author of this paper declares that there is no conflict of interest.

Author's contribution
Author CV has carried out the fabrication, data collection, data analysis, and manuscript writing. BNK guided me with the proper standard requirements throughout the research and critically reviewed the manuscript writings.

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TABLES AND FIGURES

Table 1. Mean and Standard deviation values observed for the Plain glass fiber composite and Glass fiber reinforced composite

Group Statistics					
	Group	**N**	**Mean**	**Std. Deviation**	**Std Error Mean**
Cylindricity Tolerance	Plain Glass Fiber	20	80.31105	.28546	.06383
	Glass fiber composite reinforced with aluminium wire mesh	20	70.6513	.72760	.16270

Table 2. The independent sample test on Hardness shows the significance P=0.025 measured for with and without filler. There is a significant difference between the groups.

Independent Samples Test									
Cylindricity Tolerance	**Levene's Test 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	5.460	0.025	55.273	38	.000	9.65995	.17477	9.30615	10.01375
Equal variances not assumed			55.273	24.714	.000	9.65995	.17477	9.29979	10.02011

Table 3. Damaged area (mm^2) in the drilling of Glass Fiber composite recorded from the ImageJ software for both control and experimental groups

S.NO	Plain Glass Fiber	Glass Fiber reinforced with aluminium wire mesh
1	80.342	71.012
2	80.462	70.143
3	80.46	70.422
4	80.152	70.564
5	80.007	70.467
6	79.809	72.912
7	80.026	70.071
8	80.428	70.366
9	80.244	71.438
10	80.52	70.235
11	80.506	70.257
12	80.578	71.426
13	80.38	70.575
14	80.348	71.012
15	79.648	70.892

16	80.345	70.912
17	80.591	70.071
18	80.822	70.583
19	80.064	69.305
20	80.492	70.364

Fig. 1. Plain Glass Fiber Composite After drilling

Fig. 2. Glass Fiber Reinforced With Aluminium Wire mesh after drilling

Fig. 3. CNC Drilling machine setup used for drilling of Glass fiber composite material

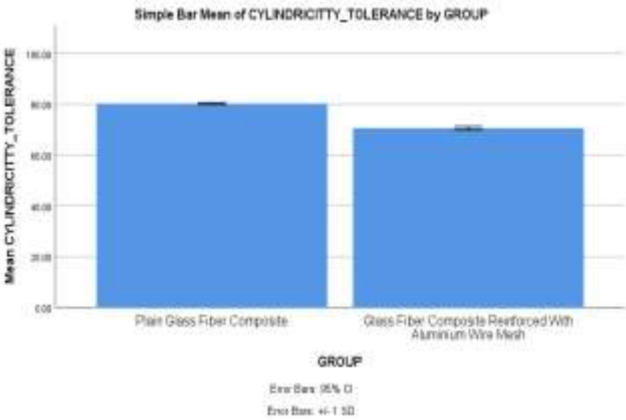

Fig. 4. Mean bar graph of Cylindricity tolerance obtained for plain glass fiber and Glass fiber reinforced with aluminium wire mesh. The mean Cylindricity tolerance of plain glass fiber is higher than glass fiber reinforced with aluminium wire mesh. Mean Cylindricity tolerance (mm²) ± 1 SD.