

# Comparative Analysis of Hole Surface Quality in CNC Drilling of Novel Sisal Fibre Reinforced Aluminium Wire Mesh Sandwich Composite and Sisal Fiber Laminate With 90° /0° /90° Ply Orientation Angle

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## Abstract

**Aim:** Comparison of surface roughness during novel drilling the natural fibre metal composite laminate of novel sisal fibre and aluminum mesh layered in the form of sandwich (sisal - aluminium - sisal - aluminium - sisal) with sisal reinforced composite laminate. The unidirectional sisal fibre is laid in 90°/0°/90° orientation in both the laminates considered for comparison.

**Materials and Methods:** The work material chosen for this study is aluminium wire mesh of grade 6092 and unidirectional sisal fibre. The type of drill bit selected for novel drilling operation is tungsten carbide drill bit. The Sisal fibre reinforced laminates were manufactured in two groups (Experiment group =1 and Control Group =1). Sample sizes for each group were 20 with pre-test power of 80%, beta=0.05%, and CL 95%.

**Result:** An experimental study is selected with 20 samples per group and surface roughness is measured for both the work samples and analyzed for its significance by spss software and the graphs were plotted and level of significance was found to be  $p = 0.023$  ( $p < 0.005$ ).

**Conclusion:** Within the limitations of the study, the experimental group of novel sisal fibre reinforced with aluminium wire mesh sandwich composite (sisal - Al - sisal - Al - sisal) with 90° /0° /90° ply orientation angle gives the good surface finish with 8.06% improvement in reducing surface roughness value in comparison with base materials.

**Keywords:** Novel Sisal fibre, Aluminium wire mesh, Drilling, Surface Roughness, Tungsten carbide drill bit, Epoxy, Hardener

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## INTRODUCTION

The main aim of this research is to compare the surface roughness of the layered sisal with aluminium mesh in between the sisal fibre composite as (sisal - aluminium - sisal - aluminium - sisal) by novel drilling the 20 number of holes on the composite using tungsten carbide drill . This hybrid composite consists of an alternative thin layer of aluminium mesh plies and sisal fibre reinforced epoxy layer (Goel and Kundal 2019). The fibre-metal composite combines the advantages of metal materials and fibre reinforced composite systems. The most widely used metal in fiber laminates is aluminium (Al). The Aluminium mesh is extremely lighter in weight, has very low density, has high strength, good corrosion resistance and also available at cheaper rate (Thirumurugan et al. 2016). The natural fibres are being cost effective and easily available yields high potential in various commercial and industrial applications such as interior works of passenger cars, panels for partition and fall ceiling, partition cupboards, fibers in packing, furniture applications, as covering materials in geotextiles for soil protection,

enhancing the barrier properties. The utilization of natural fibres has identified a growth in various applications (Cheluka 2020).

The total number of articles published for the past ten years related to this research area are around 836 in Google scholar and 146 in ScienceDirect. Here the development and analysis of surface roughness on the sisal fibre is compared with the sisal fibre reinforced with the aluminium wire mesh sandwich composite and the sisal fibre at 90°/0°/90° of ply orientation angle. The epoxy and hardener used for fabrication, and tungsten coated drill bits (make: T.A.S.P) are used to drill the holes on sandwich composite laminate. Thus investigation on aluminium wire mesh, banana fibre and glass fibre reinforced hybrid composite has come across glass aluminium foil/wire mesh (Thirumurugan et al. 2016). Banana fibre glass hybrid composite has the highest flexural strength and hybrid tensile load capacity when compared to other two composite types. Effect of sisal fibre orientation on mechanical properties of sisal fibre reinforced epoxy composite (Chand and Jain 2005). The surface roughness is highly recommended by cutting speed rather than feed rate and the tool angle (Chand and Jain 2005; Goel and Kundal 2019). Influencing of surface roughness of carbon fibre on properties of carbon fibre reinforced plastics (Baurova, Zorin, and Prikhod'ko 2015). Analysis of the properties of glass/sisal/polyester reinforced composite. Among the available literature considered, the closely related best study is the analyzing the properties of the reinforced natural fibre composite (Baloyi et al. 2021). 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). From the past literature on the surface quality in natural fibres and parameters of drilling, there is only limited research on fibre metal sandwich laminate. The expertise in this research is theoretical and experimental knowledge on fabricating sandwiched fibre metal laminates. The aim of the present work is to compare the hole surface quality in CNC novel drilling of novel sisal fibre reinforced aluminium wire mesh sandwich composite and sisal fibre composite with 90°-0-90° of ply orientation angle.

## MATERIALS AND METHODS

The specimens were fabricated by hand layup technique in Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai. No ethical approval was required since this project is regarding fabrication of fibre metal composites. In this study, sisal fiber reinforced epoxy composite laminate was taken as a control group with the sample size of 20, and novel sisal fibre reinforced aluminium wire mesh sandwich composite was taken as an experimental group with the sample size of 20. The pre-test power for testing was 80%, Alpha=0.05% and CL was 95%, G power test was used to fix the number of samples for each group (Khan et al. 2021).

The raw materials used to fabricate the composite materials are sisal fibre which is extracted through a process known as decortication, where leaves are crushed, beaten, and brushed away by a rotating wheel set with blunt knives, so that only fibres remain where used and aluminium wire mesh. The sisal fibre used is unidirectional and which is collected from Fiber region, Chennai, India. For fabricating the composite, epoxy LY-556 and the hardener LH-556 which has good mechanical and thermal properties are procured from Hayavel Aerospace India Pvt Ltd, Chennai, india.

The surface roughness quality is to be measured to the sisal fibre composite. Fig. 2 shows the epoxy and hardener used for fabrication to composites the sisal and aluminium and aluminium wire mesh, and the Fig. 1 shows the sisal fibre and aluminium wire mesh of cutted material used for fabricating the laminate. The method used to fabricate the composite material reinforced with sisal fibre reinforced aluminium wire mesh is the hand layup method. The final dimensions of the composite material after the fabrication is 150 x 150 mm of thickness 5 mm. In the hand layup method the number of plies used is five as (sisal - aluminium - sisal - aluminium - sisal) for fabrication. The epoxy and the hardener are mixed for the fabrication process in the ratio of 2:1 for quick and proper bonding between the plies. The hand layup method is used in this research for fabricating the sisal and aluminium wire mesh composite. The resin is uniformly spread with the help of the brush. The second layer of sisal fibre is kept and a roller is moved with the mild pressure to entrap the air between the plies. The process is repeated for each layer of sisal fibre, till the layers are stacked as per the ASTM standards. After curing at room temperature or at specific temperature the developed composite is then allowed to drill for measuring the surface roughness.

Now in the experimental and control group the epoxy and hardener used is 20% and 10% in the ratio of 10:1 volume fraction; the hardener is poured into the beaker and the hardener is poured accordingly within the ratio

and mixed well for 5 minutes. Then the mould is kept around 24 hours for curing. After curing the specimen is removed and the sharp edges are corrected by the secondary operation as per the ASTM standards.

In order to implement the composite into daily life usage, some of the properties were to be measured, studied and compared for safety and reliability. Hence surface roughness is measured and compared to ensure that which has high surface roughness by comparing the data. The specimen depends upon the experimental group and control group for the comparison of surface roughness quality to determine which surface roughness.

## STATISTICAL ANALYSIS

The statistical analysis of SPSS V26 is used to determine the standard deviation, standard error, mean values. Also with the probability value of  $p < 0.005$  was noted as a significant value. In this experiment, the independent variables are spindle speed, drill bit diameter of 8mm, and feed rate and the dependent variable is surface roughness. The independent sample T-test was used to analyze the significance of surface roughness value with and without aluminium wire mesh of sisal fibre reinforced composite laminate (Iernutan, Babota, and Istoan 2019).

## RESULTS

The experimental and analysis details of the work carried out on sisal fibre reinforced with aluminium wire mesh composite sandwich laminate are described here. Fig. 6 shows the graphical representation of Surface Roughness ( $\mu\text{m}$ ) for Group-1 (Novel Sisal Fibre Reinforced Aluminium Wire Mesh Sandwich Composite Laminate) and Group-2 (Sisal Fibre Composite Laminate). Table 1 and Table 2 shows details of measured value of surface roughness and group statistical analysis done for samples prepared with and without aluminium wire mesh. By performing an Independent t-test analysis, The result of a data set is statistically significant to  $p = 0.023$  ( $< 0.05$ ) according to statistical analysis. Table 3 shows the Independent t-test details (mean and std-deviation) obtained using SPSS software.

## DISCUSSION

The samples are prepared as per the ASTM standards for machining shown in Fig. 3. The novel drilling operation is performed on the novel drilling machine under the different machining conditions such as feed rate (mm/min) and speed (rpm). The several samples are drilled for evaluating the surface roughness of the drilled hole. The tungsten carbide of 8 mm diameter is used to drill the holes on sample using a CNC drilling machine. Fig. 4 shows the tungsten carbide drill used for the drilling process. The CNC novel drilling machine was used to drill the holes on the fabricated composite of sisal reinforced with aluminium wire mesh. (Won 1999). From the graph, the mean value of the surface roughness of sisal fibre laminate was  $2.2305 \mu\text{m}$  with the maximum and minimum values were  $2.061$  and  $2.346 \mu\text{m}$  respectively. The mean value of the surface roughness of the sisal fibre reinforced with aluminium wire mesh as sandwich layer composite is  $2.4444 \mu\text{m}$  and with maximum and minimum values were  $2.135$  and  $2.354 \mu\text{m}$  respectively. Therefore from the graph the surface roughness is better in the sisal fibre laminate than the sisal fibre reinforced with aluminium wire mesh composite. The results obtained were subjected to the one way ANOVA analysis using spss v2.6 statistical software. In statistical analysis table 2, the mean value of surface roughness of sisal fibre reinforced with aluminium wire mesh is  $2.2305$  and standard deviation is  $0.146171$  the mean value of sisal fibre laminate is  $2.444$  and the standard deviation is  $0.27096$ . From ANOVA Table 3, the significance level of the surface roughness is determined  $p = 0.000$  ( $p < 0.5$ ). Significance value for the surface roughness of the sisal fibre composite with aluminium wire mesh compared with sisal fibre composite without aluminum wire mesh was statistically significant  $p = 0.023$  ( $p < 0.05$ ).

The roughness quality test is performed in the roughness testing machine, ( mitutoyo ) to compare the experimental and control group to find out in which the surface quality is good (Baurova, Zorin, and Prikhod'ko 2015). Table 1 shows that the surface roughness quality is tested using the roughness testing machine for the accurate value of readings to compare the experimental group and the control group. Fig. 5 shows the surface roughness measuring instrument used to measure the surface quality of the drilled holes. The drilling is performed in the composites by varying speed, feed and work material (Reddy et al. 2019). Totally 20 holes were drilled and tested and the surface quality of the holes is determined. The mean values are determined by the spss software. The output from the spss software, the values are in table 2 and 3 (Cheluka 2020). By comparing both the values from the experimental values and control group within the SPSS software, then concluded by the output by the spss software that the surface finish is high in the sisal fibre laminate without aluminium wire mesh (sisal - sisal - sisal - sisal - sisal) with the ply orientation angle of 90 degree, and the speed and feed rate also affects the quality of the surface finish of the hole. So that it also should be selected carefully to get a good surface finish (Baurova, Zorin,

and Prikhod'ko 2015). By comparing and analyzing the results obtained by measuring the surface roughness the sisal fibre laminate has good surface quality when compared to reinforced aluminium wire mesh composite (Thirumurugan et al. 2016).

The limitation of the present study is the hand layup fabrication method which is a time consuming process. Hence, it may not be suitable for mass production. However the bonding between the fibre matrix and epoxy is more important which reduces the surface roughness and strength of the composite. In the future scope, the compression molding method can be adopted for the fabrication process of sandwich laminates.

## CONCLUSIONS

Within the limitations of this study, The surface roughness of novel sisal fibre reinforced with aluminium wire mesh sandwich composite and sisal fibre laminate of 90°/0°/90° of ply orientation angle were measured and compared with standard stipulations. This study indicates that sisal fibre laminate possesses more surface roughness than the novel sisal fibre reinforced with aluminium wire mesh sandwich composite with 8.06% improvement in surface roughness value in comparison with base materials.

## DECLARATION

### Conflict of Interests

The authors of this research declare no conflict of interest.

### Authors Contribution

Author GA was involved in data collection, data analysis and manuscript writing. Author GRD was involved in conceptualization, data validation and critical review of the manuscript.

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## TABLES AND FIGURES

**Table 1.** This table shows the values of surface roughness with the varying speed and feed rate of 20 samples of 8mm diameter hole

Surface Roughness ( $\mu\text{m}$ )		
S.No	Sisal Fibre laminate	Novel Sisal Fibre Reinforced Aluminium Wire Mesh Sandwich Composite Laminate
1.	2.135	2.061
2.	2.197	2.418
3.	2.458	2.061
4.	2.616	2.171
5.	2.018	2.318
6.	2.491	2.412
7.	2.187	2.067
8.	2.818	2.141

9.	2.145	2.134
10.	2.341	2.014
11.	2.514	2.324
12.	2.891	2.456
13.	2.417	2.098
14.	2.331	2.419
15.	2.485	2.221
16.	2.714	2.146
17.	2.147	2.425
18.	2.981	2.131
19.	2.648	2.248
20.	2.354	2.346

**Table 2.** Descriptive table represents the highest mean value of surface roughness is 2.4444 μm found at Group 2 a standard deviation of 1.1225μm

GROUP	N	MEANS	STANDARD DEVIATION	STD. ERROR MEANS.
Novel Sisal Fibre Reinforced Aluminium Wire Mesh Sandwich Composite Laminate	18	2.2305	0.14671	0.03281
Sisal Fibre laminate	18	2.4444	0.27096	0.06059

**Table 3.** Independent sample test represents the significant value of surface roughness between and within the groups is  $p = 0.023$  ( $p < 0.05$ )

Independent Samples Test									
	Levene's test for equality for variances		t	df	Sig. (2-tailed)	T-test for equality of means		95% confidence interval of difference	
	F	Sig.				Mean difference	Std. Error Difference	Lower	Upper

Equal variances assumed	5.596	0.023	3.104	38	.004	0.21385	0.06890	0.35333	0.07437
Equal variances not assumed			3.104	29.2	.004	0.21385	0.06890	0.35471	0.07299



**Fig. 1** Sisal fibre and aluminium wire mesh



**Fig. 2** Epoxy and Hardener



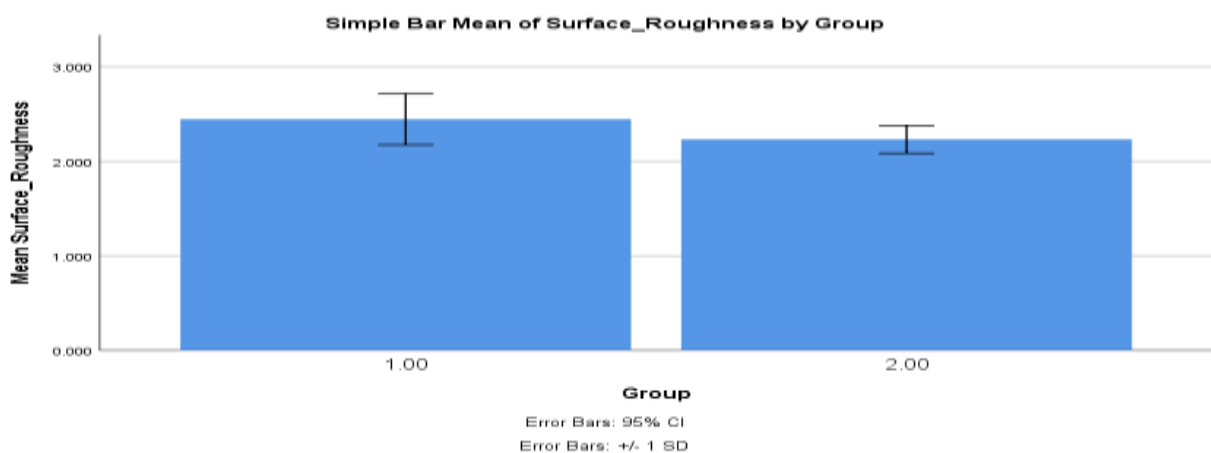
**Fig. 3** Drilled sample of novel sisal fibre reinforced with aluminium wire mesh sandwich laminate



**Fig. 4** Tungsten Carbide drill used



**Fig. 5** Surface Roughness Testing Machine



**Fig. 6** Graphical representation of Surface Roughness(  $\mu\text{m}$  ) for Group-1 (Novel Sisal Fibre Reinforced Aluminium Wire Mesh Sandwich Composite Laminate) and Group-2 (Sisal Fibre Composite Laminate ), X axis: Material groups, Y axis: Surface Roughness(  $\mu\text{m}$  ) with Mean accuracy of detection 95% CI and +/- 1 SD.