Original Article

Comparative Analysis of hole surface quality in CNC Drilling of Novel Sisal Fibre Reinforced Aluminium Wire Mesh Sandwich Composite and Sisal Fiber Laminate with 45°/0°/45° Ply Orientation Angle

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Abstract

Aim: Comparing and analyzing the surface roughness of the CNC Novel Drilling of sisal fibre reinforced with aluminium wire mesh sandwich composite and sisal fibre composite with 45^0 /0^0 /45^0 ply orientation angle.
Materials and methods: The examination of surface roughness during penetrating the drill on sisal fiber metal composite overlay of sisal and aluminium wire mesh layered as sandwich (sisal - aluminium - sisal - aluminium - sisal) with sisal built up composite cover. The unidirectional sisal fiber is laid in 45°/0°/45° direction in both the overlays considered for correlation. The work material picked for this review is aluminium wire lattice of grade 6092 and unidirectional sisal fiber. 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%.
Results:A test study is chosen with samples for every group and surface roughness is estimated for both the experimental group and control group and analyzed for its significance by SPSS software and the graphs were plotted and level of significance was found to be 0.031 ($p<0.005$).
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 45^0 /0^0 /45^0 ply orientation angle gives the good surface finish with 26.5% improvement in surface roughness value in comparison with base materials..

Keywords: Novel Sisal Fibre, Surface Roughness, Drilling, Epoxy, Tungsten Carbide, Aluminium Wire Mesh.

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INTRODUCTION

The main aim of this research is to analyze the surface roughness of hole surface drilled in sisal fibre reinforced with aluminium wire mesh laminate using sisal layer as an alternative layers in the laminate (sisal - aluminium - sisal - aluminium - sisal) by using tungsten carbide drill. The drilling is carried out by using the CNC drill machine. This composite comprises alternate layers of aluminium wire mesh and sisal fiber supported by epoxy layer (Cheluka 2020). The fiber-metal composite consolidates the upsides of metal materials and fiber supported composite frameworks. The most broadly utilized metal in fiber metal composites is aluminium (Al). The aluminium wire mesh is incredibly lighter in weight, has extremely low thickness, has high strength, great consumption opposition and furthermore accessible at less expensive rate (V. Shanmugam et al. 2021). The surface roughness is strongly suggested by cutting the face as opposed to taking care of feed rate and speed. The cutting power of the tool is needed to create the great surface finish of the hole. The commercial and industrial applications of sisal fibre laminate are 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 (Kumar and Sing 2017).

The total number of articles published for the past ten years related to this research area are around 810 in google scholar and 135 in science directly. Here the development and analysis of hole surface roughness on the sisal fibre is compared with sisal fibre reinforced with the aluminium wire mesh sandwich composite and sisal fibre at 45°/0/45°of the ply orientation angle. The epoxy and the hardener used for the fabrication and tungsten coated drill bits are used to drill the holes on the sandwich composite laminate.(Sathishkumar, Ramakrishnan, and Navaneethakrishnan 2021). Thus Assessing fibre surface treatment to improve the mechanical properties of natural fibre composites the research is about obtain fibre strength and stiffness data is described, and the statistical treatment that can be applied to this type of data and the influence of treatment conducted to improve interfacial strength on the mechanical properties of natural fibre are explored (Pickering 2011)).Experimental investigation of surface roughness in drilling hybrid structural composites such, a new hybrid structural composite was fabricated with red mud as filler and sisal fibre as reinforcement in polyester matrix(V. Shanmugam et al. 2021). Aging effects on natural fibre reinforced polymer composite, durability and life prediction this focuses on the phenomenon of natural fiber-based composites under various aging conditions and proposes suitable solutions to improve the response of natural fiber-reinforced composite to aging conditions such as moisture, seawater, hygrothermal, and natural and accelerated wealth (Bourhis, Le Bourhis, and Touchard 2021) . The best paper related to the current study is the investigation of surface roughness in drilling hybrid composites (V. Shanmugam 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; R. Shanmugam et al. 2021; Rajasekaran et al. 2020; Adhinarayanan et al. 2020; Rajesh et al. 2020; Aurtherson et al. 2021)

There is only limited research on machining of natural fibre based sandwich laminates. Taking this as a research gap, the study on measuring and comparing the surface roughness of holes created in sisal fibre reinforced aluminium laminate is carried out in this research project. 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 45°-0-45° of ply orientation angle.

MATERIALS AND METHODS

The specimens were fabricated by the hand layup method in Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai. In this research the 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. G power calculator was used to calculate the sample size of the composite.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 (Muthukumar, n.d.)(Sood and Singh 2021)(Muthukumar, n.d.)**.**

The sisal fibre which is used to fabricate the composite materials which is extracted through the process known as decortication, where the leaves are crushed ,beaten ,and brushed away by rotating wheel set with blunt knives. The method used to create the composite material supported with aluminium wire mesh was the hand layup method The size of the laminate was 150 mm x 150 mm of thickness 5 mm. (sisal - aluminium - sisal - aluminium - sisal) for fabrication.

The epoxy and the hardener are blended for the fabrication process in the proportion of 10:1 for fast and legitimate holding between the layers. The epoxy and hardener is consistently spread with the assistance of the brush. The second layer of sisal fiber is placed and a roller is moved with the gentle strain to entangle the air between the layers. The cycle is repeated for each layer of sisal fiber, till the required thickness of 5 layers are obtained. The curing is done at room temperature or at explicit temperature ((Khan et al. 2021). The other laminates considered for the experimental group are also done by the same procedure. After curing the specimen is removed and the sharp edges are machined by the secondary operation as per the ASTM standards as shown in Fig. 1.

Drilling was performed on the Novel Drilling machine under the distinctive machining conditions, for example, feed rate (mm/min) and speed (rpm) (Sultan et al. 2020). All the samples are drilled for assessing the surface roughness of the drill hole. The tungsten carbide of 8 mm diameter was utilized to drill the holes using a CNC Novel Drilling machine.

The surface roughness measurement was carried out using the roughness measuring machine (mitutoyo) shown in Fig. 2 to compare the experimental and control groups in order to determine which group has the best surface quality.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.

STATISTICS ANALYSIS

The statistical analysis of SPSS V.26 was used to determine the standard deviation, standard error, mean values. Aslo with the probability value of $p<0.005$ was noted as significant value. In this experiment the independent variables are spindle speed, drill bit diameter of 8mm, and feed rate. The independent sample T-test was used to analyse the significance of with and without aluminium wire mesh composite if sisal fibre reinforced with aluminium wire mesh composite (Bourhis, Le Bourhis, and Touchard 2021).

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. 3 shows the graphical representation of Surface Roughness (μm) 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 $p = 0.031$ (<0.05) according to statistical analysis. Table 3 shows the Independent t-test details (mean and std-deviation) obtained using IBM-SPSS software.

DISCUSSION

The samples are prepared as per the ASTM standards for machining. 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. The CNC novel drilling machine was used to drill the holes on the fabricated composite of sisal reinforced with aluminium wire mesh. From the graph, the mean value of the surface roughness of sisal fibre laminate was 2.27017 μm with the maximum and minimum values were 2.084 and 1.321 μm respectively. The mean value of the surface roughness of the sisal fibre reinforced with aluminium wire mesh as sandwich layer composite is 2.7080 μm and with maximum and minimum values were 3.214 and 2.286 μm 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 2.7080 and standard deviation is 0.29947 the mean value of sisal fibre laminate is 2.27017 and the standard deviation is 0.295004 From ANOVA Table 3, the significance level of the surface roughness is determined $p=0.031$ ($p<0.5$). 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 $p=0.031$ ($p<0.05$).

The surface roughness quality is performed in the roughness testing machine, (mitutoyo) to compare the experimental group and the control group to find out if the surface quality is good (Ramesh and Deepa 2021). The hand layup method is the time consuming process. So, that it is not 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. This project can be overdone in the future by taking chaos properties and analysis (Prabhu et al. 2022). 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 ((Khan et al. 2021). The output from the spss software, the values are in the table 2 and 3. By comparing both the values from the experimental group 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 play orientation angle of 45 degree, and the speed and feed rate also affects the surface finish of the hole (Won 1999). So that it also should be selected carefully to get a good surface finish. By comparing and analyzing the results obtained by measuring the surface roughness of the sisal fibre laminate has good surface quality when compared to sisal fibre reinforced with aluminium wire mesh composite (Sood and Singh 2021).

The limitations of the present study is the hand layup method which involves the human resources with the limitations such as air traps, low concentration and fibre in proper degree. Hence, the future scope of the project is to adopt a compression moulding method to fabricate the sandwich laminates. Further many natural fibres can be used for investigation.

CONCLUSION

Within the limitations of the study, the surface quality of novel sisal fibre reinforced with aluminium wire mesh sandwich composite and sisal fibre laminate of 45^0 /0/45^0 ply orientation angle were measured and compared with standard stipulations. The experimental group of novel sisal fibre reinforced with aluminium wire mesh sandwich composite (sisal - Al - sisal - Al -sisal) with 45^0 /0^0 /45^0 ply orientation angle gives the good surface finish with 26.5% improvement in surface roughness value in comparison with base materials.

DECLARATIONS

Conflict of Interest

The authors of this paper declare no conflict of interest

Authors Contribution

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

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REFERENCES

1. Adhinarayanan, Rajesh, Aravindh Ramakrishnan, Gopal Kaliyaperumal, Melvinvíctor De Poures, Rajesh Kumar Babu, and Damodharan Dillikannan. 2020. “Comparative Analysis on the Effect of 1-Decanol and Di-N-Butyl Ether as Additive with diesel/LDPE Blends in Compression Ignition Engine.” *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, June, 1–18.
2. Arun Prakash, V. R., J. Francis Xavier, G. Ramesh, T. Maridurai, K. Siva Kumar, and R. Blessing Sam Raj. 2020. “Mechanical, Thermal and Fatigue Behaviour of Surface-Treated Novel Caryota Urens Fibre–reinforced Epoxy Composite.” *Biomass Conversion and Biorefinery*, August. https://doi.org/10.1007/s13399-020-00938-0.
3. Aurtherson, P. Babu, Bhanu Teja Nalla, Karthikeyan Srinivasan, Kulmani Mehar, and Yuvarajan Devarajan. 2021. “Biofuel Production from Novel Prunus Domestica Kernel Oil: Process Optimization Technique.” *Biomass Conversion and Biorefinery*, May. https://doi.org/10.1007/s13399-021-01551-5.
4. Bhansali, Karan J., Kamlesh R. Balinge, Subodh U. Raut, Shubham A. Deshmukh, M. Senthil Kumar, C. Ramesh Kumar, and Pundlik R. Bhagat. 2021. “Visible Light Assisted Sulfonic Acid-Functionalized Porphyrin Comprising Benzimidazolium Moiety for Photocatalytic Transesterification of Castor Oil.” *Fuel* 304 (November): 121490.
5. Bourhis, Eric Le, Eric Le Bourhis, and Fabienne Touchard. 2021. “Mechanical Properties of Natural Fiber Composites.” *Encyclopedia of Materials: Composites*. https://doi.org/10.1016/b978-0-12-819724-0.00009-4.
6. Cheluka, Saikrupa. 2020. “Flexural Strength and Effect of Drilling Parameters on Surface Roughness, Circularity of Natural Fiber Composites.” *International Journal for Research in Applied Science and Engineering Technology*. https://doi.org/10.22214/ijraset.2020.1121.
7. Deepanraj, B., N. Senthilkumar, D. Mala, and A. Sathiamourthy. 2021. “Cashew Nut Shell Liquid as Alternate Fuel for CI Engine—

optimization Approach for Performance Improvement." *Biomass Conversion and Biorefinery*, February. https://doi.org/10.1007/s13399-021-01312-4.
8. Jayanth, Bellappu Venkat, Melvin Victor Depoures, Gopal Kaliyaperumal, Damodharan Dillikannan, Dilipsingh Jawahar, Kumaran Palani, and Ganesha Prasad Meravanigee Shivappa. 2021. "A Comprehensive Study on the Effects of Multiple Injection Strategies and Exhaust Gas Recirculation on Diesel Engine Characteristics That Utilize Waste High Density Polyethylene Oil." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, June, 1–18.
9. Kamath, Manjunath, Subha Krishna Rao, Jaison, Sridhar, Kasthuri, Gopinath, Sivaperumal, and Shantanu Patil. 2020. "Melatonin Delivery from PCL Scaffold Enhances Glycosaminoglycans Deposition in Human Chondrocytes – Bioactive Scaffold Model for Cartilage Regeneration." *Process Biochemistry* 99 (December): 36–47.
10. Khan, Anish, M. R. Sanjay, Suchart Siengchin, Mohammad Jawaid, and Abdullah M. Asiri. 2021. *Hybrid Natural Fiber Composites: Material Formulations, Processing, Characterization, Properties, and Engineering Applications*. Woodhead Publishing.
11. Kumar, Dhiraj, and K. K. Sing. 2017. "Experimental Analysis of Delamination, Thrust Force and Surface Roughness on Drilling of Glass Fibre Reinforced Polymer Composites Material Using Different Drills." *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2017.07.095.
12. Muthukumar, Chandrasekar. n.d. *Aging Effects on Natural Fiber-Reinforced Polymer Composites: Durability and Life Prediction*. Springer Nature.
13. Pickering, K. L. 2011. "Assessing Fibre Surface Treatment to Improve the Mechanical Properties of Natural Fibre Composites." *Interface Engineering of Natural Fibre Composites for Maximum Performance*. https://doi.org/10.1533/9780857092281.1.186.
14. Prabhu, P., A. Balaji, D. Jayabalakrishnan, N. Velmurugan, P. Vimalnathan, B. Karthikeyan, V. Balaji, and S. Dinesh. 2022. "Study on Machining Parameters and Mechanical Properties of Hybrid Agave Sisalana and Glass Fiber-Reinforced Polyester Composites (A/GFRP)." *Journal of Natural Fibers*. https://doi.org/10.1080/15440478.2022.2036288.
15. Rajasekaran, S., D. Damodharan, K. Gopal, B. Rajesh Kumar, and Melvin Victor De Poures. 2020. "Collective Influence of 1-Decanol Addition, Injection Pressure and EGR on Diesel Engine Characteristics Fueled with diesel/LDPE Oil Blends." *Fuel* 277 (October): 118166.
16. Rajesh, A., K. Gopal, De Poures Melvin Victor, B. Rajesh Kumar, A. P. Sathiyagnanam, and D. Damodharan. 2020. "Effect of Anisole Addition to Waste Cooking Oil Methyl Ester on Combustion, Emission and Performance Characteristics of a DI Diesel Engine without Any Modifications." *Fuel* 278 (October): 118315.
17. Raju, P., K. Raja, K. Lingadurai, T. Maridurai, and S. C. Prasanna. 2021. "Glass/Caryota Urens Hybridized Fibre-Reinforced nanoclay/SiC Toughened Epoxy Hybrid Composite: Mechanical, Drop Load Impact, Hydrophobicity and Fatigue Behaviour." *Biomass Conversion and Biorefinery*, March. https://doi.org/10.1007/s13399-021-01427-8.
18. Ramesh, M., and C. Deepa. 2021. "Mechanical Properties of Natural and Synthetic Fiber Reinforced Hybrid Composites." *Hybrid Natural Fiber Composites*. https://doi.org/10.1016/b978-0-12-819900-8.00013-1.
19. Sathishkumar, T. P., S. Ramakrishnan, and P. Navaneethakrishnan. 2021. "Mechanical Behaviors of Aluminum Filler and Jute Fiber Mat Reinforced Epoxy Hybrid Composites." *Hybrid Natural Fiber Composites*. https://doi.org/10.1016/b978-0-12-819900-8.00006-4.
20. Sathiyamoorthi, Ramalingam, Gomathinayakam Sankaranarayanan, Dinesh Babu Munuswamy, and Yuvarajan Devarajan. 2021. "Experimental Study of Spray Analysis for Palmarosa Biodiesel-diesel Blends in a Constant Volume Chamber." *Environmental Progress & Sustainable Energy* 40 (6). https://doi.org/10.1002/ep.13696.
21. Shanmugam, Rajasekaran, Damodharan Dillikannan, Gopal Kaliyaperumal, Melvin Victor De Poures, and Rajesh Kumar Babu. 2021. "A Comprehensive Study on the Effects of 1-Decanol, Compression Ratio and Exhaust Gas Recirculation on Diesel Engine Characteristics Powered with Low Density Polyethylene Oil." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 43 (23): 3064–81.
22. Shanmugam, Vigneshwaran, Uthayakumar Marimuthu, Sundarakannan Rajendran, Arumugaprabu Veerasimman, Adamkhan Mahaboob Basha, Mohd Shukry Bin Abdul Majid, Rasoul Esmaeely Neisiany, et al. 2021. "Experimental Investigation of Thrust Force, Delamination and Surface Roughness in Drilling Hybrid Structural Composites." *Materials* 14 (16). https://doi.org/10.3390/ma14164468.
23. Sood, Mohit, and Satsimran Singh. 2021. "Recent Advancements in Thermal Properties and Behavior of Modified Natural Fiber Composites." *Hybrid Natural Fiber Composites*. https://doi.org/10.1016/b978-0-12-819900-8.00001-5.
24. Sudhakar, M. P., Merlyn Ravel, and K. Perumal. 2021. "Pretreatment and Process Optimization of Bioethanol Production from Spent Biomass of Ganoderma Lucidum Using Saccharomyces Cerevisiae." *Fuel* 306 (December): 121680.
25. Sultan, Mohamed Thariq Hameed, Azwan Iskandar Azmi, Mohd Shukry Abd Majid, Mohd Ridzuan Mohd Jamir, and Naheed Saba. 2020. *Machining and Machinability of Fiber Reinforced Polymer Composites*. Springer Nature.
26. Won, Myong-Shik. 1999. *Machining of Fiber-Reinforced Composite Laminates*.
27.

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.

Surface Roughness (µm)		
Exp. No.	**Novel Sisal Fibre Reinforced Aluminium Wire Mesh Sandwich Composite Laminate**	**Sisal Fibre laminate**
1.	2.286	2.084
2.	2.894	2.392

3.	2.307	2.162
4.	2.606	2.332
5.	2.572	2.312
6.	2.432	2.235
7.	2.955	2.148
8.	2.672	2.617
9.	2.419	2.118
10.	2.569	2.519
11.	2.656	2.321
12.	2.735	2.216
13.	2.319	2.346
14.	2.878	2.211
15.	2.937	2.681
16.	3.180	1.016
17.	3.104	1.217
18.	3.223	1.114
19.	3.112	1.221
20.	3.214	1.321

Table 2. Descriptive table represents the highest mean value of surface roughness is 2.270800 μm found at Group 2 a standard deviation of 2.27017 μm.

Group	N	Means	Standard Deviation	Std Error Means
Novel Sisal Fibre Reinforced Aluminium Wire Mesh Sandwich Composite Laminate	20	2.70800	.299472	.070586
Sisal Fibre laminate	20	2.27017	.295004	.069533

Table 3. Independent sample test represents the significant value of surface roughness between and within the groups is p = 0.031 (p<0.05)

Independent Sample Test								
Levene's Test		**T**	**Df**	**Sig (2-Tailed)**	**T Test For Equality of Means**		**Confidence Interval of Difference**	
F	**Sig**				**Mean Difference**	**Std Error Difference**	**Lower**	**Upper**
0.235	0.031	4.419	34	0.000	.437833	.099082	.23647	.639193
		4.419	33.992	0.000	.437833	.099082	.23647	.639194

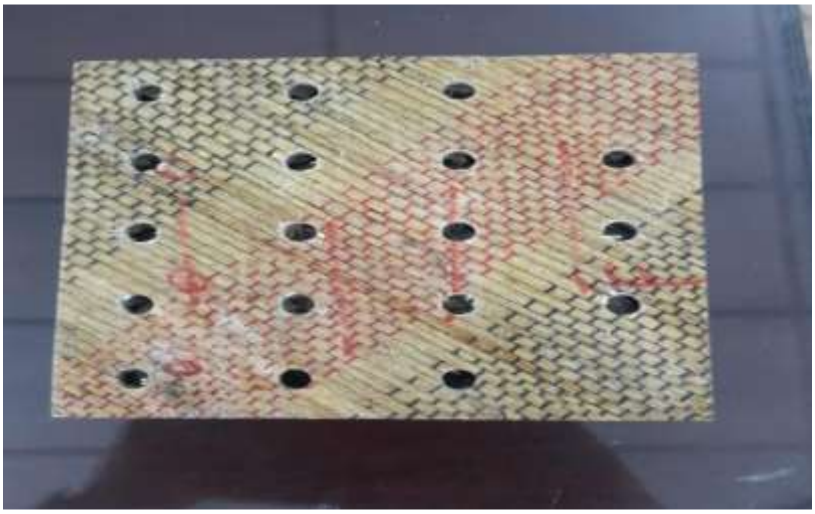

Fig. 1. Drilled sample of fabricated sisal and aluminium wire mesh after drilling process

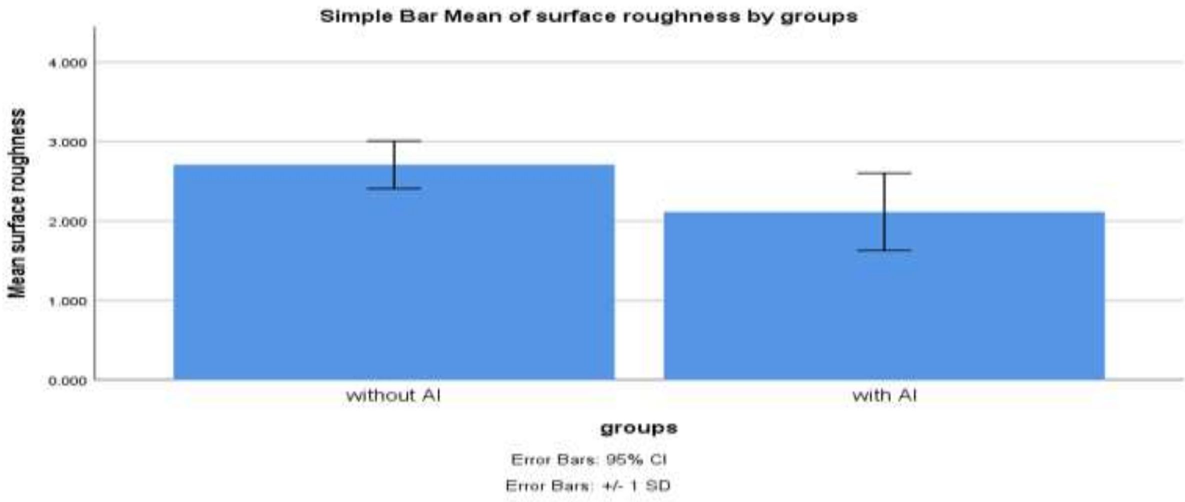

Fig. 3. Graphical representation of Surface Roughness(μm) for Group-1 (Novel Sisal Fibre Reinforced Aluminium Wire Mesh Sandwich Composite Laminate) and Group-2 (Sisal Fibre Composite Laminate), X axis: Material groups, Y axis: Surface Roughness(μm) with Mean accuracy of detection 95% CI and +/-1 SD.