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Genetic Algorithms: A Solution to Fiber Reinforced Composite Drilling Challenges

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Abstract: ***Natural fiber composites are a group of materials that have gained increasing attention in recent years due to their potential to replace traditional materials in various applications. However composite materials are made up of layers of fibers and resin that can separate from each other during drilling, leading to delamination. This paper proposes a multi-objective optimization approach for drilling natural fiber composites, considering three key drilling parameters: cutting speed, feed rate and tool geometry. The objective is to minimize delamination and thrust force. Multiple linear regression analysis is employed to develop the regression equations for each objective function, which are then optimized simultaneously using a multi-objective genetic algorithm (MOGA). The results demonstrate that the proposed approach can effectively identify the optimal drilling parameters that balance the trade-offs between the competing objectives. The proposed approach can be useful for improving the efficiency and quality of drilling natural fiber composites, which are increasingly used in various industrial applications.***

Keywords: Drilling, Natural fiber, Genetic algorithm

I. INTRODUCTION

Natural fiber reinforced composites are an attractive alternative to traditional synthetic composites because they are renewable, biodegradable, and offer potential cost savings[1]. However, drilling natural fiber reinforced composites presents some unique challenges and requirements[2]. Drilling of natural fiber composites is necessary in many applications where holes need to be created for fastening, joining, or assembly purposes.

One of the primary challenges in drilling natural fiber reinforced composites is their inherent anisotropy. The fibers are typically aligned in a particular direction, and drilling through them can cause damage to the fibers or create irregular hole geometries. Therefore, it is essential to carefully control the drilling parameters, such as feed rate and spindle speed, to prevent damage and ensure consistency in the hole shape and size.

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Another challenge is the variability in the physical and mechanical properties of natural fibers, which can affect the drilling process. For example, different types of natural fibers have different densities, moisture content, and mechanical properties, which can affect the heat generated during drilling and the tool wear. Thus, it is crucial to select appropriate drilling tools and parameters that can accommodate the variability in the fiber properties. Additionally, natural fiber reinforced composites are prone to delamination, which can occur during drilling due to the high thrust forces and heat generated. Delamination can weaken the structure and reduce the load-bearing capacity of the composite. Therefore, it is crucial to select appropriate drill bits and techniques that can minimize the risk of delamination. In summary, drilling natural fiber reinforced composites requires careful consideration of the anisotropy and variability in fiber properties, as well as the risk of delamination. Proper selection of drilling tools and techniques can help overcome these challenges and ensure high-quality and consistent holes. Several parameters can affect the quality of drilled holes in NFCs, including cutting parameters (spindle speed, feed rate etc.), material parameters (fiber orientation, fiber content, fiber properties and matrix properties) and tool parameters (tool diameter, tool geometry, tool material etc.) [3]. Optimizing these parameters can result in high-quality drilled holes in NFCs with minimal issues such as delamination, fiber pullout, and surface roughness. Therefore, the optimization of drilling parameters, such as cutting speed, and feed rate, is essential to minimize these challenges and achieve high-quality drilled holes in NFRCs. Optimization of drilling variables for natural fiber composites (NFCs) has been the subject of numerous studies in recent years. In particular, the use of multi-objective optimization approaches has gained significant attention, given the need to balance the trade-offs between competing objectives, such as minimizing delamination, surface roughness, and tool wear, while maximizing material removal rate and productivity. Several researchers have employed response surface methodology (RSM) and genetic algorithms (GA) to develop predictive models and optimize drilling variables simultaneously [4-6]. For instance, Mercy et al. [7] used GA to optimize drilling variables for pineapple fiber composites. The results showed that the proposed approach could identify optimal drilling parameters that minimized thrust force while maximizing material removal rate. One of the prior study on multi-objective optimization of drilling variables in NFCs was conducted by Jayabal and Natarajan [4], who used RSM and genetic algorithm (GA) to optimize the drilling parameters for minimizing thrust force, tool wear and torque while maximizing material removal rate.

The authors developed a mathematical model using response surface methodology (RSM) to predict the objective functions and validated the results using analysis of variance (ANOVA). The study concluded that the optimized drilling parameters improved the quality of drilled holes in NFCs.

In another study, Feito et al. [8] used a multi-objective approach (MOPSO) algorithm to optimize the drilling parameters for minimizing thrust force, delamination, and torque. The authors developed a predictive model using RSM and validated the results using the ANOVA method. The study showed that the optimized drilling parameters improved the quality of drilled holes in NFCs.

To date, limited research has been conducted on the optimization of drilling variables for NFCs, and no study has addressed the multi-objective optimization of drilling variables for natural fiber reinforced composites, using genetic algorithms.

In this context, this paper proposes multi-objective optimization approaches for drilling NFRCs that identifies the optimal drilling parameters. The proposed approach can help improve the efficiency and quality of drilling NFRCs, which can have significant implications for various industrial applications.

II. MATERIALS AND METHODS

The input variables considered in this study are spindle speed(n), feed rate(mm/rev), and drill point angle (p). L27 Factorial design was employed to design the experiments, and a multi-objective optimization approach based on the genetic algorithm used to determine the optimal combination of drilling variables that yield the best drilling performance. Design of experiments was performed using MINI TAB software. Thrust force and delamination factor are taken as response variables. The statistical analysis of the experimental data is carried out using analysis of variance (ANOVA). Experimental data for carrying out further analysis is collected through literature survey [9]. However a approach for implementing the multi objective genetic algorithm for solving the challenges during the drilling of composites is presented in this research article. A full factorial strategy is considered for implementation of ANOVA. Regression equation for thrust force (TF), delamination factor (DF) and torque (TQ) were further obtained using multiple linear regression analysis. Spindle speed and feed rate were identified as continuous predictors whereas drill bit with different point angle were considered as categorical predictor.

III. RESULTS AND DISCUSSION

1.1 Statistical Modeling of Experimental Data

Response variable and input variables values are mentioned in Table 1.

Table 1- Input and Response Variable

Sr. No.	Point angle (degree)	feed rate (mm/rev)	Spindle speed (RPM)	Delamination factor (DF)	TF (N)
1	118	0.05	3000	1.1129	17.48
2	118	0.05	1500	1.0735	19.01
3	90	0.05	1500	1.1002	9.85
4	104	0.25	3000	1.0345	48
5	118	0.25	1500	1.1028	54.11
6	90	0.15	3000	1.08	25.12
7	104	0.15	1500	1.0162	32.75
8	104	0.15	3000	1.0239	23.59
9	104	0.05	4500	1.0584	11.38
10	104	0.25	4500	1.0437	40.38
11	90	0.15	4500	1.0545	22.06
12	118	0.15	3000	1.0532	37.32
13	104	0.05	1500	1.0204	11.38
14	90	0.15	1500	1.0383	25.11
15	90	0.05	3000	1.1194	9.85
16	90	0.05	4500	1.1446	9.85
17	90	0.25	3000	1.059	35.8
18	90	0.25	4500	1.0935	38.85
19	118	0.15	1500	1.0557	32.75
20	118	0.05	4500	1.1704	19.01
21	118	0.15	4500	1.1016	29.69
22	118	0.25	4500	1.1268	43.43
23	104	0.05	3000	1.0513	11.38
24	118	0.25	3000	1.0909	48.01
25	104	0.25	1500	1.0392	51.06
26	104	0.15	4500	1.021	28.17
27	90	0.25	1500	1.0901	40.38

Table 2 represents the regression equations for TF and DF. Regression equations were obtained using multiple linear regression analysis in MINI Tab software. Interaction between the parameters and second order terms were also included in the model to improve accuracy. The value of R^2 for all cases is greater than 85%, which represents a good fit of data to the model. Feed rate in regression is shown by x(1) and spindle speed is shown with the help of x(2).

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Table 2. Regression Equations

Response variable	Point angle (°)	Equation	R^2(%)
TF	90	0.37 + 184.0*x(1) - 0.00024*x(2) + 34*x(1)*x(1) + 0.000000 x(2)*x(2)- 0.01272*x(1)*x(2)	97.26
	104	4.95 + 184.0*x(1) - 0.00024*x(2) + 34*x(1)*x(1) + 0.000000*x(2)*x(2) - 0.01272*x(1)*x(2)	
	118	9.70 + 184.0*x(1) - 0.00024 x(2) + 34 x(1)*x(1) + 0.000000 x(2)*x(2)- 0.01272 x(1)*x(2)	
DF	90	1.1083-0.920*x(1) +0.000008*x(2)+3.571* x(1)*x(1) + 0.000000*x(2)*x(2) - 0.000082* x(1)*x(2)	86.23
	104	1.0559 - 0.920 x(1) + 0.000008 x(2) + 3.571 x(1)*x(1) + 0.000000 x(2)*x(2) - 0.000082 x(1)*x(2)	
	118	1.0559 - 0.920*x(1) + 0.000008*x(2) + 3.571 x(1)*x(1) + 0.000000*x(2)*x(2) - 0.000082* x(1)*x(2)	

1.2 Optimization

Multi-objective optimization was performed to obtain the minimum delamination factor and thrust force value for drill bit having 90-degree point angle. Multi objective -genetic algorithm solver of MATLAB was utilised to minimize the objective functions. Default values of algorithm parameters such as population size, number of generations, mutation and cross over function etc. were consideration for solving the problem. Solution and corresponding value of objective functions are mentioned in Table 3.

Table 3- Solution and Objective function value

Drill tool point angle 90				
	Solution		Objective	
Index no	Feed rate (mm/rev)	Spindle speed	TF	DF
1	0.116934582	4167.9431	15.15113	1.042928
2	0.152541884	4191.113102	20.09083	1.03216
3	0.050406958	4200.520307	6.02987	1.087241
4	0.055302523	4200.830802	6.686383	1.0829
5	0.174668231	4197.197647	23.21368	1.030015
6	0.064919486	4186.786422	7.996304	1.074831
7	0.061093097	4183.463869	7.483012	1.077933
8	0.095730058	4223.693068	12.1391	1.053588
9	0.091189564	4208.069819	11.5406	1.056299
10	0.085760754	4200.166056	10.81014	1.059729
11	0.135539975	4206.341773	17.67243	1.036107
12	0.05912009	4197.891464	7.202593	1.079623
13	0.123794287	4230.797622	15.99173	1.040034
14	0.146302821	4243.129637	19.10278	1.033178
15	0.074239071	4234.48039	9.202394	1.067779
16	0.076315905	4189.921991	9.537247	1.066187
17	0.177552821	4243.207762	23.51003	1.029695
18	0.167102858	4238.915679	22.03896	1.030108

Pareto front chart is shown in Figure 1, it shows variation of objective 1 and objective 2 with corresponding index number. Objective 1 represents the thrust force value and objective 2 on y-axis represents the delamination factor values.

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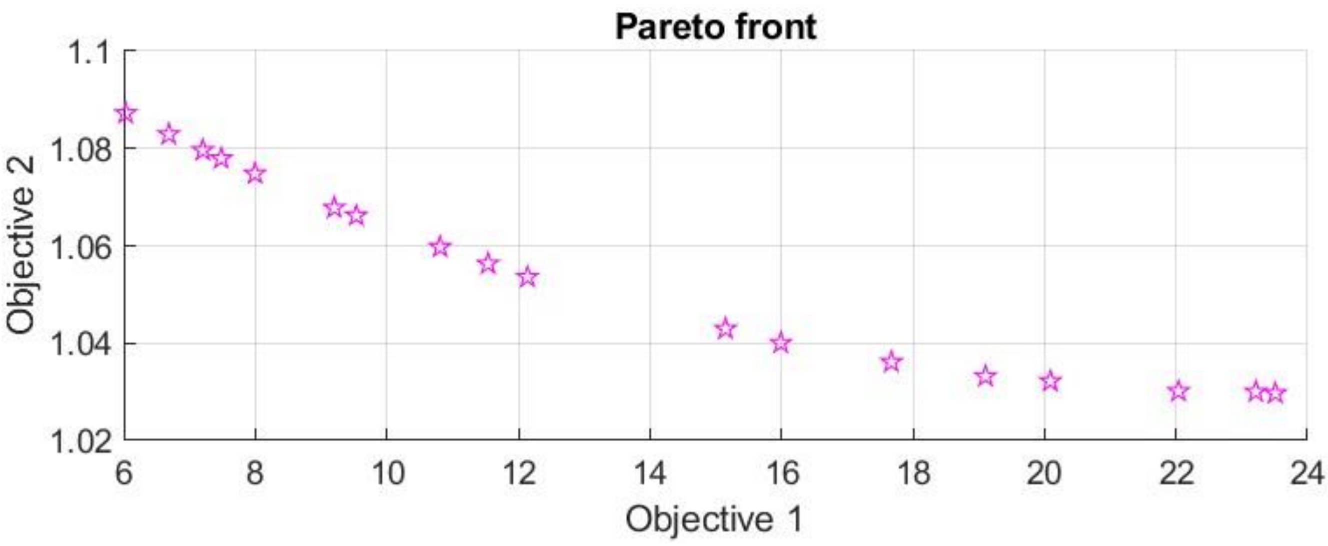

Figure 1- Pareto front for TF and DF

In a similar manner, multi-objective optimization for the other two drill bits can also be performed.

IV. CONCLUSION

1. Regression equations were obtained using multiple linear regression analysis.
2. Solution and objective function values were obtained using multi objective genetic algorithm.
3. The optimal value of thrust force and delamination factor was found at high spindle speed and medium value of feed rate.
4. Variation of objective function values with indexing number is also represented with the help of pareto front chart.

DECLARATION

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REFERENCES

1. Kannan G, Thangaraju R (2022) Recent Progress on Natural Lignocellulosic Fiber Reinforced Polymer Composites: A Review. J Nat Fibers 19:7100–7131. https://doi.org/10.1080/15440478.2021.1944425 [CrossRef]
2. Malik K, Ahmad F, Gunister E (2021) Drilling Performance of Natural Fiber Reinforced Polymer Composites: A Review. J Nat Fibers 00:1–19. https://doi.org/10.1080/15440478.2020.1870624 [CrossRef]
3. Arputhabalan J, Prabhu S, Palanikumar K, et al (2019) Assay of machining attributes in drilling of natural hybrid fiber reinforced polymer composite. Mater Today Proc 16:1097–1105. https://doi.org/10.1016/j.matpr.2019.05.201 [CrossRef]
4. Jayabal S, Natarajan U (2010) Optimization of thrust force, torque, and tool wear in drilling of coir fiber-reinforced composites using Nelder-Mead and genetic algorithm methods. Int J Adv Manuf Technol 51:371–381. https://doi.org/10.1007/s00170-010-2605-7 [CrossRef]
5. (2022) Genetic Optimization of Machining Parameters Affecting Thrust Force during Drilling of Pineapple Fib _ Enhanced Reader.pdf
6. Belaadi A, Boumaaza M, Alshahrani H, Bourchak M (2022) Delamination in drilling of jute / cork - reinforced polymer biosandwich materials: optimization by response surface methodology and genetic algorithm. Int J Adv Manuf Technol 122:2095–2111. https://doi.org/10.1007/s00170-022-10001-z [CrossRef]
7. Lilly Mercy J, Sivashankari P, Sangeetha M, et al (2022) Genetic Optimization of Machining Parameters Affecting Thrust Force during Drilling of Pineapple Fiber Composite Plates-an Experimental Approach. J Nat Fibers 19:1729–1740. https://doi.org/10.1080/15440478.2020.1788484 [CrossRef]
8. Feito N, Muñoz-Sánchez A, Díaz-Álvarez A, Miguelez MH (2019) Multi-objective optimization analysis of cutting parameters when drilling composite materials with special geometry drills. Compos Struct 225:. https://doi.org/10.1016/J.COMPSTRUCT.2019.111187 [CrossRef]
9. Chaudhary V, Gohil PP (2016) Investigations on Drilling of Bidirectional Cotton Polyester Composite. Mater Manuf Process 31:960–968. https://doi.org/10.1080/10426914.2015.1059444 [CrossRef]

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