PART - A

ENGINEERING & TECHNOLOGY

Parametric optimization of drilling variables and water absorption behaviour of prosopis juliflora fiber reinforced epoxy composite using taguchi analysis

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Abstract

The paper studied the drilling behaviour of prosopis juliflora fiber-based composite. The drilling experiments were performed as per the L_{27} taguchi orthogonal array. Effect of drill bit diameter (mm), spindle speed (rpm) and feed rate (mm/min) on thrust force (kgf) and surface roughness (µm) have been studied. Feed rate, drill bit diameter and spindle speed were found to have the greatest effects on thrust force. Similarly, drill bit diameter played most influencing factor for surface roughness followed by feed rate and spindle speed according to analysis of variance and signal to noise ratio. The regression coefficient (R^2) for the thrust force and SR are 98.80% and 99.80%, respectively, indicating an empirical relationship between the parameters and responses. It was observed from the SEM analysis that the lower drill bit diameter, spindle speed and feed rate reveal fiber pullout, matrix bonding and matrix cracking. The least amount of water consumed at the longer exposure duration of 192 hours indicates that the Prosopis juliflora fiber-based composite has reached near saturation. Rate of absorption significantly decreases as the material reaches its optimum ability to retain water. The response SR of 4.97 µm and thrust force of 2.65 kgf were attained at optimized conditions; 6 mm, 2220 rpm, 80 mm/min.

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The obtained desirability function for surface roughness and thrust force were 0.987 and 0.857 respectively, and combined desirability for the present optimization was 0.92., which was close to 1. Thus, the parametric levels of the experiment are within the operating limit.

Keywords: Natural composite, drilling, prosopis juliflora fiber, Taguchi, surface roughness

1. Introduction

Composite materials are receiving considerable attention in diverse engineering applications owing to their advantageous characteristics such as high strength-to-weight ratio, corrosion resistance and versatility [1]. Natural fiber-reinforced composites have emerged as promising alternatives to traditional synthetic fiber composites, owing to their eco-friendly nature, abundant availability and cost-effectiveness [2]. In particular, Prosopis juliflora fiber derived from the mesquite tree have shown promising mechanical properties and have been extensively studied for their potential applications in composite materials [3]. Polyester resin has been widely used as a matrix material in composite manufacturing due to its excellent mechanical properties, chemical resistance and ease of processing. When combined with natural fiber such as Prosopis juliflora, polyester resin binder composites exhibit enhanced mechanical performance making them suitable for various structural applications [4]. One critical aspect of utilizing composite materials in practical engineering applications is their machinability, particularly drilling behaviour, which directly impacts manufacturing processes such as assembly, fabrication, and quality control. Understanding the drilling behaviour of composite materials is essential for optimizing machining parameters minimizing tool wear, and ensuring dimensional accuracy of machined components [5]. Despite the growing interest in natural fiber reinforced polyester resin composites, there is a lack of comprehensive studies investigating their drilling behaviour, especially concerning Prosopis juliflora fiber composites [6]. Therefore, this study aims to experimentally investigate the drilling behaviour of Prosopis juliflora fiber composite through a series of drilling tests.

Fibers from Prosopis juliflora are becoming more and more popular in the field of composite materials, especially when combined with binders made of polyester. Ganesan et al. [7] conducted experimental investigation on mechanical behaviour of hybrid composites based on natural fibers, specifically Calotropis gigantea and Prosopis juliflora using Taguchi-Grey Relational analysis to improve these composites' mechanical properties. Raja et al. [8] studied the delamination and drilling behaviour of neem and banyan fiber reinforced sawdust particles hybrid composite through response surface methodology. The best drilling parameters according to an ANOVA are a drill bit diameter of 6 mm, a feed rate of 10 mm/rev, and a spindle speed of 1500 rpm. The minimum thrust force of 23.43 N and torque of 5.13 N-m was attained. Mercy et al. [9] investigated the drilling behaviour of teak wood reinforced epoxy resin using taguchi L_9 orthogonal array. Effect of spindle speed and feed rate on thrust force and temperature was studied during the drilling process. From the effect plots, it was studied that as speed increase, thrust force decrease and temperature increases. Conversely, thrust force increases and temperature decrease, as feed rate increase. Mohan Kumar et al. [10] conducted investigation on drilling characteristics of palmyra sprout fiber natural composite. The investigation uses rotating speed, tool feed, and resins as drilling process parameters. The results revealed that the candlestick drill bit produced lower thrust force under the given drilling conditions, with the twist and step cone drill bits. Rajaraman et al. [11] investigated drilling process parameters for kenaf and banana-based composite materials. They utilized high-speed steel drill bits of three different diameters and employed the L9 factorial method for their experimental study. They determined that a spindle speed of 3000 rpm and a feed rate of 150 mm/min were optimal for producing defect-free holes. Patel et al. [12] investigated the drilling process parameters on the composite based on kenaf and bananas. For the experimental investigation, three distinct diameters of high-speed steel were employed, together with the L9 factorial approach. They came to the conclusion that holes devoid of defects could be produced at a spindle speed of 3000 rpm and 150 mm/min.

Prosopis Juliflora fiber-based composites have gained attention due to their potential applications in various industries. However, understanding the drilling behaviour of these composites is crucial for optimizing manufacturing processes. The thrust force and surface roughness are critical parameters affecting the quality and efficiency of drilling operations. Therefore, there is a need to investigate the influence of different parameters on thrust force and surface roughness during the drilling of Prosopis Juliflora fiber-based composites. The problem statement aims to identify the key parameters and their optimal levels to minimize thrust force and surface roughness, thereby enhancing the drilling performance and quality of the composite material. This study will employ Taguchi analysis to systematically evaluate the effects of parameters and optimize the drilling process for Prosopis Juliflora fiber-based composites.

2. Materials and Methods

In this investigation, Prosopis juliflora Fiber, Vetiver Fiber and Coir pith were selected as the natural fiber. Polyester resin, Cobalt and Catalyst were chosen as matrix materials. The properties of natural fibres used in the study were given in Table 1. The composition of the matrix and reinforcement materials are Prosopis juliflora Fibers-40%, Vetiver fiber-25%, Coir pith 13%, Polyester resin-14%, Cobalt- 6%, Catalyst-2%. The compression molding machine with pressing speed of 25 mm/sec, maximum pressing capacity of 25 Tons, Heating range of 145°C and Working pressure = 25 kg/cm^2 was used in the study. Methyl ethyl ketone peroxide serves as the curing system for vinyl ester resin, while cobalt activator is employed for polyester resin. The Prosopis juliflora fiber extracted for this investigation was depicted in Fig. 1.

Table 1. Properties of Natural fibres used in the composite

Properties	Prosopis Juliflora Fiber	Vetiver Fiber	Coir pith
Density (g/cm^3)	0.9	1.5	1.1
Tensile Strength (MPa)	393 -773	247 – 723	131 – 175
Young's Modulus (GPa)	13.0 – 26.5	12.0 – 49.8	4.0 – 6.0
Elongation at Break (%)	1.1 – 1.5	1.6 – 2.4	3.0 – 7.0

Fig. 1 Extracted prosopis juliflora fiber

2.1 Preparation of fibres and composite

The prosopis juliflora fiber (JPF) was collected with a minimum average moisture content of 5.44%. Subsequently, it underwent room drying for 5 days in order to get average moisture content of 5.18%. Then, the fiber was physically crushed using a wooden mortar and pestle. The PJF particles were subjected to conditioning in an oven set at 60°C for a duration of 24 hours. This process aimed to attain a new equilibrium moisture content, which settled at 3% of the initial moisture level. The vetiver fiber (VF) was sourced from the seashore areas of the southern region of Cuddalore district, initially with a moisture content of 10.54%. The moisture content was analysed with the aid of MX-50 moisture analyser. Then, it underwent a room drying process for 5 days, followed by oven drying at 60°C for 24 hours until the moisture content was reduced to 8.41%. The Coir pith is another raw material, which was obtained from the coir plant with an initial moisture content of 5.54%. It was initially room dried for 3 days and subsequently subjected to oven drying at 60°C for 24 hours until the moisture content decreased to 3.41%.

After the preparation of the all fibres, the particle board panel was developed using a compression molding machine with heating range of 145°C and working pressure = 25 kg/cm^2. The proportions indicated in the table are expressed in weight percentage and the materials were manually mixed by hand. Subsequently, the polyester resin powder was blended with the fiber and hexamine. Additionally, the curing agent cobalt with a proportion of 10:1, was incorporated into the mixture. The arrangement of fibers and addition of resin is shown in Fig. 2. Finally, the prepared mixture was placed into the mold. The apparatus was activated and the temperature was adjusted to 145°C. Subsequently, the mold was kept in the apparatus. Following that, the composite material underwent compression with heat for a duration of 6 minutes and without heat for a period of 30 minutes. Afterward, the board was removed from the frame and cut into regular sizes for the drilling processes. The final developed composite board is depicted in Fig. 3

Fig. 2 Fabrication of prosopis juliflora fiber composite

Fig. 3 Developed composite board

2.2 Experimental details.

The drilling experiment was conducted using vertical milling machine centre (Model: FEELER-FV1000A) and is shown in Fig .4. The experiments were carried out by varying three distinct parameters drill bit diameter (mm), spindle speed (rpm), and feed rate (mm/min). The process parameters and levels used for the drilling investigation is Table 2. Figure 5 illustrates the drill bits of varying diameters used in the study.

Fig. 4 Vertical milling machine centre (Model: FEELER-FV1000A)

Table 2 Drilling parameters and their levels

Parameter	Unit	Levels		
		Low	**Medium**	**High**
Drill bit Diameter	mm	6	8	10
Spindle speed	rpm	740	1480	2220
Feed rate	mm/min	80	160	240

Fig. 5 Drill bit with different diameter used in the study

2.3 Design of Experiments

As design of experiment, Taguchi method was chosen for this study because of its suitability for handling three process parameter and levels [13]. The taguchi L_{27} full factorial method was implemented to carry out the experiments. output responses measured in the study are thrust force and surface roughness. L27 orthogonal array test was employed to reduce the number of experiments. The maximum signal-to-noise (S/N) ratio value is regarded as the optimal value for minimizing the thrust force and surface roughness. The characteristics of drilling was assessed with smaller the better as given in Eq. (1).

$$\frac{S}{N} = -\log 10\left[\frac{1}{n}\left(\sum y^2\right)\right] \qquad (1)$$

Where, y is the value of thrust force and surface roughness and n is the number of observations.

3. Result and Discussion

Numerous studies have demonstrated that the defects arising during the drilling of fiber-based composites are closely correlated with the thrust force and surface roughness generated during the drilling process. The axial force was assessed by employing various geometrical drill bits to drill the prosopis juliflora fiber, vetiver fiber and coir pith reinforced composite. Three different drill bits were used to assess the thrust force and surface roughness. The value of experimental and S/N ratio is tabulated in Table 3.

Table 3 Experimental values and S/N ration (dB)

Ex. No	Drilling Parameters			Thrust Force (kgf)		Surface roughness (µm)	
	Drill bit diameter (mm)	Spindle Speed (rpm)	Feed rate (mm/min)	Exp. Value	S/N ratio value	Exp. Value	S/N ratio value
1	6	740	80	2.3	-7.0591	6.11	-15.72
2	6	740	160	3.3	-10.2484	7	-16.90
3	6	740	240	4.0	-12.1061	8.28	-18.36
4	6	1480	80	3.2	-10.1436	5.21	-15.13
5	6	1480	160	3.8	-11.5218	6.75	-16.59
6	6	1480	240	4.7	-13.3528	7.95	-18.01
7	6	2220	80	2.3	-7.4029	4.9	-13.80
8	6	2220	160	3.2	-9.9965	6.05	-15.64
9	6	2220	240	4.3	-12.5791	7.25	-17.21
10	8	740	80	2.7	-8.5757	7.73	-17.76
11	8	740	160	3.6	-11.1838	8.56	-18.65
12	8	740	240	4.5	-13.1411	9.59	-19.64
13	8	1480	80	3.4	-10.6862	7.12	-17.05

14	8	1480	160	4.5	-13.0275	7.85	-17.90
15	8	1480	240	5.4	-14.5941	8.88	-18.97
16	8	2220	80	2.7	-8.5194	6.14	-15.76
17	8	2220	160	3.6	-11.0143	7.05	-16.96
18	8	2220	240	4.6	-13.3154	7.81	-17.85
19	10	740	80	3.4	-10.7362	9.98	-19.98
20	10	740	160	4.3	-12.7117	10.61	-20.51
21	10	740	240	5.3	-14.5264	11.15	-20.95
22	10	1480	80	3.9	-11.9143	9.05	-19.13
23	10	1480	160	4.7	-13.4179	9.68	-19.72
24	10	1480	240	5.8	-15.2461	10.48	-20.41
25	10	2220	80	3.5	-10.7765	7.91	-17.96
26	10	2220	160	4.0	-12.1384	8.18	-18.26
27	10	2220	240	5.1	-14.2142	8.96	-19.05

3.1 Analysis on thrust force

The thrust force recorded during the drilling of the natural composite is provided in Table 3. The S/N ratio analysis was used to evaluate the impact of input parameters on the output. Table 4 displays the S/N ratio for thrust force. The results of S/N ration indicated that feed rate is the most influential parameter for thrust force, followed by drill bit diameter and spindle speed. Table 5 shows the ANOVA results for thrust force. A quadratic model was developed to establish the relationship between thrust force and the independent drilling parameter using Design Expert software, The model equation for thrust force is represented by Eq. (2). The thrust force generated by drill bit with diameter of 6mm is lesser than the other drill bit diameters. At drilling with spindle speed of 740 rpm and feed rate of 80 mm/min, thrust force is minimum.

Thrust force (kgf)=2.03-0.88*A + 0.00599*B + 0.0026*C+0.0556 (A*A) - 0.000002 (B*B)- 0.000004 (C*C)-0.000011 (A*B)+0.00073 (A*C)+0.000003 (B*C)________________ (2)

R^2= 98.80%, R^2 (Adjusted)=98.16%

Table 4. S/N ratio table for thrust force

Level	Drill bit Diameter (mm)	Spindle speed (rpm)	Feed rate (mm/min)
1	-10.490	-11.143	-9.535
2	-11.562	-12.656	-11.696
3	-12.854	-11.106	-13.675
Delta	2.363	1.550	4.140
Rank	2	3	1

Table 5. ANOVA table for thrust force

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	22.1920	2.4658	155.14	0.000
Linear	3	19.4630	6.4877	408.19	0.000
A -drill bit diameter	1	4.7100	4.7100	296.35	0.000
B-Spindle speed	1	0.0027	0.0027	0.17	0.686
C-Feed rate	1	14.7503	14.7503	928.06	0.000
Square	3	2.6847	0.8949	56.31	0.000
A*A	1	0.0239	0.0239	1.50	0.237
B*B	1	2.6264	2.6264	165.25	0.000
C*C	1	0.0344	0.0344	2.16	0.160
2-Way Interaction	3	0.0443	0.0148	0.93	0.448
A*B	1	0.0376	0.0376	2.36	0.143
A*C	1	0.0066	0.0066	0.42	0.528
B*B	1	0.0001	0.0001	0.01	0.928
Error	17	0.2702	0.0159		
Total	26	22.4622			

From Fig. 6, it is evident that thrust force increases with the augmentation of drill bit diameter, spindle speed, and feed rate. However, it decreases at higher levels of spindle speed. At smaller drill bit diameter (6mm) typically results in lower thrust forces. This is because smaller drill bits remove less material per revolution, requiring less force to advance through the workpiece [14].

Conversely, larger drill bit diameters (10mm) generally require higher thrust forces due to the increased material removal per revolution. At low spindle speed (740 rpm), the drill bit rotates at a slower rate, resulting in a reduced cutting action. It leads to increase the contact time between the drill bit and the workpiece, allowing for more heat dissipation and potentially reducing friction. However, the reduced rotational speed may cause the drill bit to dwell longer in the material, potentially increasing thrust forces due to greater resistance encountered during the drilling process [15].

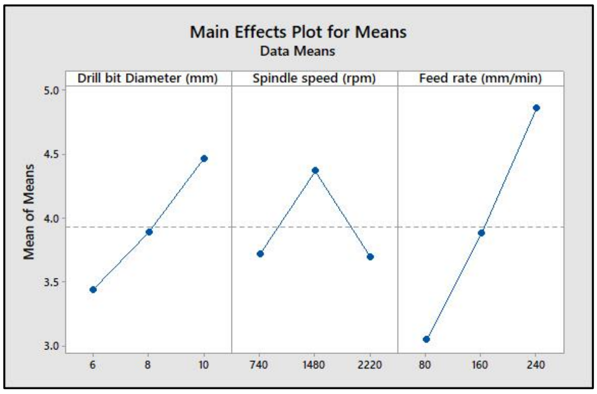

Fig. 6 Effect of drilling parameters on thrust force

At medium spindle speed (1480 rpm), the drill bit achieves a moderate rotational velocity, allowing for efficient material removal without excessive dwell time. High spindle speeds (2220 rpm) result in rapid rotation of the drill bit, enabling high cutting velocities and efficient material removal rates. Rapid rotation of the drill bit at high speed enables efficient material removal and can reduce the dwell time in the material, thereby minimizing frictional forces and potentially lowering thrust forces [16]. However, excessively high spindle speed generated excessive heat, which could lead to issues such as melting or charring of the natural composite material. The low feed rate (80 kgf) generally results in reduced thrust forces because the cutting action is less aggressive. The slower advancement allows for more controlled chip formation and evacuation, minimizing the risk of chip jamming and associated thrust force spikes. Drilling at a moderate feed rate (160 kgf) results in moderate thrust force, providing a good compromise between productivity and machining quality. It allows for efficient material removal while still maintaining control over chip formation and evacuation [17]. At higher feed rate (240 kgf), the generated heat and friction will be high, potentially leading to issues such as melting or charring of the natural composite material.

3.2 Analysis of surface roughness

Table 6 presents the S/N response table for surface roughness. It is noted from the response table that drill bit diameter is the most significant parameter for surface roughness followed by feed rate and spindle speed. It is confirmed as per the values of influencing parameter given in Table 7. The model equation for thrust force is represented by Eq. (3). Figure 7 displays the main effect plots for surface roughness. It was noted from the graph that the surface increases with an increase in drill bit diameter and feed rate, but decreases with increasing spindle speed.

Surface roughness (µm) =1.166+0.264*A + 0.001603*B + 0.01985*C + 0.06306 (A*A) - 0.000000 (B*B) + 0.000013 (C*C) - 0.000197 (A*B) - 0.001620 (A*C) -0.000000(B*C) __ (3)

R^2= 99.80%, R^2 (Adjusted)=98.69%

Table 6. S/N ratio table for surface roughness

Level	Drill bit Diameter (mm)	Spindle speed (rpm)	Feed rate (mm/min)
1	-16.37	-18.72	-16.92
2	-17.84	-18.10	-17.90
3	-19.55	-16.94	-18.94
Delta	3.18	1.78	2.01
Rank	1	3	2

Table 7. ANOVA table for surface roughness

Model	DF	Adj SS	Adj MS	F-Value	P-Value
Linear	9	65.8573	7.3175	927.86	0.000
A -drill bit diameter	3	63.3526	21.1175	2677.72	0.000
B-Spindle speed	1	37.5556	37.5556	4762.08	0.000
C-Feed rate	1	12.1032	12.1032	1534.70	0.000
Square	1	13.6939	13.6939	1736.40	0.000
A*A	3	0.6764	0.2255	28.59	0.000
B*B	1	0.3817	0.3817	48.40	0.000
C*C	1	0.2508	0.2508	31.80	0.000
2-Way Interaction	1	0.0439	0.0439	5.57	0.030
A*B	3	1.8283	0.6094	77.27	0.000
A*C	1	1.0208	1.0208	129.44	0.000
B*B	1	0.8060	0.8060	102.20	0.000
Error	1	0.0014	0.0014	0.18	0.678
Total	17	0.1341	0.0079		

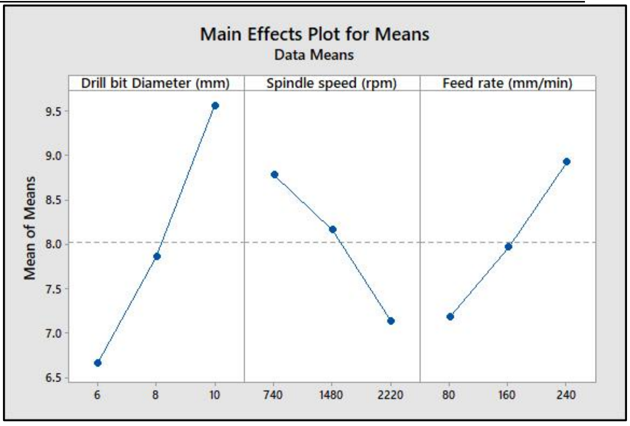

Fig. 7 Effect of drilling parameters on surface roughness

At smaller drill diameter (6mm), cutting area in contact with the natural composite surface is reduced. This limited cutting-edge engagement means that each cutting edge removes less material per revolution compared to larger diameter drill bits. As a result, the surface may experience more localized stresses and irregularities, leading to higher roughness values [18]. At larger diameter drill bits (10mm), surface area in contact with the workpiece, resulting in reduced friction and heat generation during drilling. Lower temperatures help minimize softening of the natural composite material and reduce the risk of surface irregularities caused by excessive heat, contributing to smoother surfaces. As spindle speed increase, surface roughness of the composite decreases [19]. The higher spindle speed (2220 rpm) result in a faster rotation of the drill bit, which reduces the time the cutting edges are in contact with the material. This reduced contact time can lead to smoother surface finishes as there is less opportunity for irregularities to form. At lower spindle speeds (740 rpm), the chip evacuation may not be as effective compared to higher speeds. This can lead to chip buildup around the cutting edges, resulting in poor cutting efficiency and increased surface roughness.

At higher feed rate (240mm/min), more quantity of material being removed per unit time, leading to higher cutting forces acting on the drill bit. These increased forces can cause more deformation and tearing of the material around the hole, resulting in higher surface roughness [20]. At the feed rate of 80mm/min, longer contact times between the cutting edges of the drill bit and the material was occurred. This prolonged contact allows for more effective cutting action, resulting in a smoother surface finish.

3.3 Microstructure analysis

Drill bit diameter has a major effect on the surface morphology drilled surface of the Prosopis juliflora fiber composite. At the diameter of 6mm, high stress concentration is occurred, which have a tendency to yield finer and more accurate holes [21] but also increase the likelihood fiber pull-out as depicted in Fig. 8a. On the other hand, the diameters of 10 mm increased frictional heat in the drilling zone, produce a more robust hole structure but also run the risk of more severe thermal breakdown and delamination as shown in Fig. 8b. Because of less heat produced at lower speed of 740 rpm, there is a greater tendency for SR, which can lead to imperfections and fiber pull out. By raising the spindle speed to 1480 rpm, it usually reduces SR and strike a compromise between little thermal impact and sufficient heat production for a cleaner cut. SR gets worse at the highest spindle speed of 2220 rpm because smoother and more precise cuts are made possible by the increased heat generated by friction [22]. Higher speeds generate more heat, which can degrade the matrix and cause matrix debonding as shown in Fig. 9. At this rate of heat generation, the matrix could still be thermally deteriorated, though. Therefore, a spindle speed of 1480 rpm, efficiently decreases SR while maintaining the microstructural integrity of the composite [23].

At a slower feed rate of 80 mm/min, drilling is gentler, which results in reduced stress on the material and a smoother morphology with fewer flaws such matrix cracking as depicted in Fig. 10a. On the other hand, this slower rate could intensify thermal impacts and result in heat related deterioration [24]. A substantial amount of impact stress is introduced when the feed rate is increased to 160 mm/min. This can cause more noticeable microstructural evolves, such as matrix deformation as given in Fig. 10b. Drilling becomes significantly more vigorous at the maximum feed rate of 240 mm/min, resulting in severe impact stress and quick material ablation. leads to delamination, matrix cracking and severe fiber damage [25], resulted increased SR.

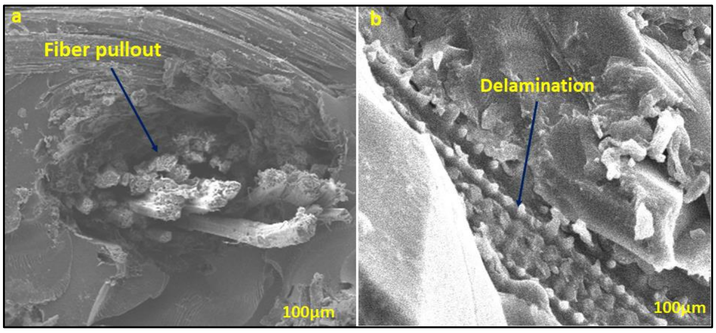

Fig. 8 Microstructure on Drill bit diameter at (a) Fiber pullout at 6 mm, (b) delamination at 10mm

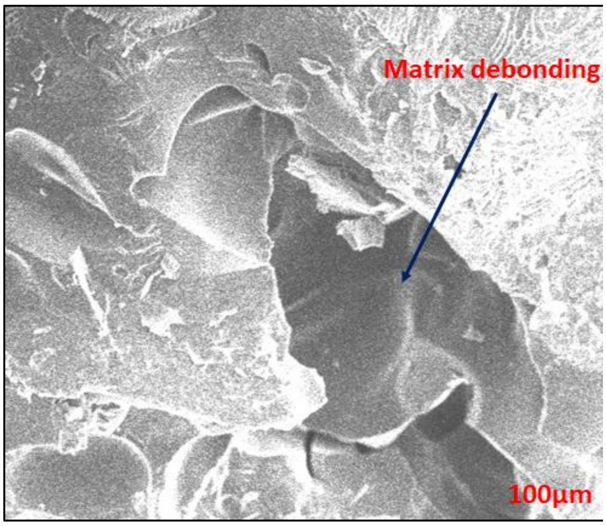

Fig. 9 Microstructure on spindle speed at (a) Matrix debonding at 2220 rpm

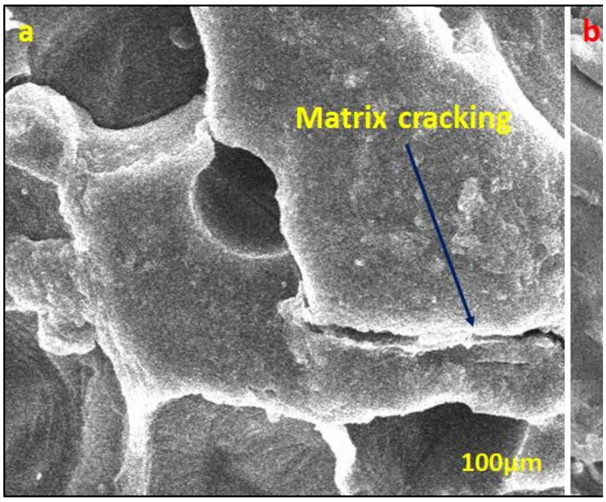

Fig. 10 Microstructure on feed rate at (a) Matrix cracking at 80 mm/min, (b) Matrix deformation at 160 mm/min

3.4 Water absorption behaviour

The water absorption behaviour of fabricated composite board is shown in Fig. 11. Natural fibers have a natural tendency to absorb moisture when they come into contact with water [26]. The mechanical properties of composite developed with natural fibers are subsequently diminished by this absorption, which also results in swelling and the formation of microcracks at the fiber-matrix interface.

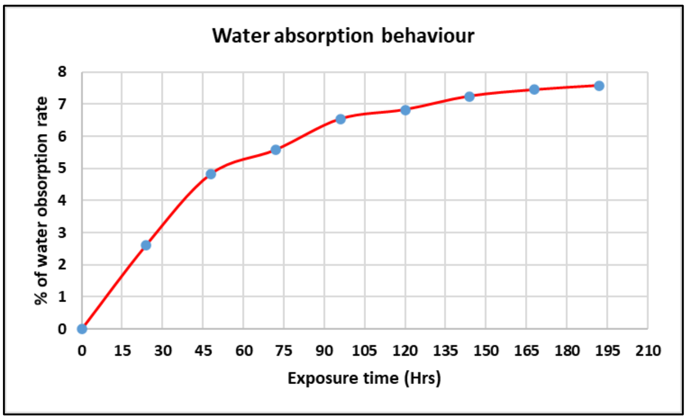

Fig. 11 Water absorption behaviour of the composite

The water absorption behaviour of the Prosopis juliflora fiber-based composite demonstrates a progressive increase in absorption over time [27]. At the beginning, the composite exhibits no moisture penetration at 0 hours. The water absorption rate increases to 2.62% after 48 hours of exposure, showing a notable uptake of moisture. By 48 hours, this rate almost doubles to 4.83%, indicating the hydrophilic nature of the composite. The absorption rate increases steadily but at lower levels, reaching 5.58% after 72 hours and 6.54% at 96 hours. The absorption rate increases to 6.83% by 120 hours and 7.25% by 144 hours. The absorption rate rises to 7.45% as the exposure period reaches 168 hours. The water absorption rate of composite finally stabilizes at 7.58% after 192 hours, indicating that it is almost at saturation. The ability of the composite to absorb water is demonstrated by the slow increase in water absorption and subsequent plateau [28], which could have an effect on the mechanical properties of the composite after extended exposure.

4. Confirmation test

In this work, response surface optimization is used to optimize process parameters that are regulated during drilling of the natural composites. The objective of the optimization is to minimize the thrust force and surface roughness. In order to optimize the appropriate parameter, the minimum value of thrust force and surface roughness were found during the optimization process. As illustrated in Fig. 12, the parametric levels of drill bit diameter (6 mm), spindle speed (2220 rpm), and feed rate (80 mm/min) offered minimized the surface roughness value of 4.97µm and thrust force of 2.65 kgf. The prediction test results of the surface roughness and thrust force is displayed in Table 8. The error percentage for thrust force and surface roughness were 1.85% and 4.5 % respectively. The combined desirability for the drilling investigation was 0.92, and the achieved desirability function for the surface roughness and thrust force were 0.98 and 0.85, which are close to one. As a result, the parametric levels of the investigation fall inside the operating range.

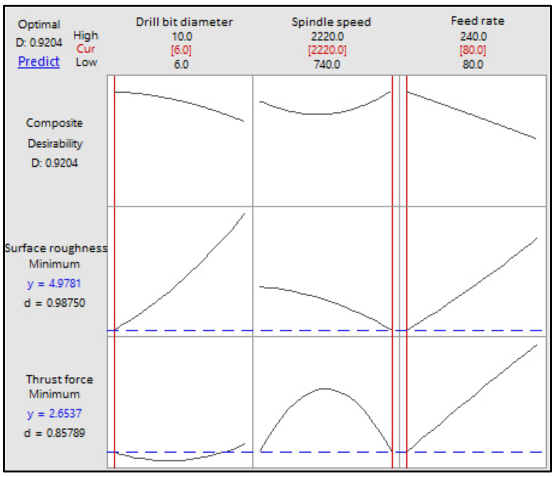

Fig. 12 Optimization table for thrust force and surface roughness

Table 8. Prediction results for thrust force and surface roughness

S.No	Drill bit diameter	Spindle speed	Feed rate	Thrust force (kgf)			Surface roughness (µm)		
				Predicted	Actual	Error	Predicted	Actual	Error
1	6	2220	80	2.65	2.7	1.85	4.97	5.71	4.6

5. Conclusion

The drilling analysis has been performed on the prosopis juliflora fiber using Taguchi method. Three parameters namely drill bit diameter, spindle speed and feed rate were selected for the investigation. The results indicated that drill diameter of 6 mm produced minimum thrust force during the drilling process. The S/N ratio results showed that feed rate, drill bit diameter, and spindle speed are the parameters that have the greatest influence on thrust force. It was showed that drill bit diameter was most important parameters for surface roughness, followed by feed rate and spindle speed. Thrust force increases with increasing of drill bit diameter spindle speed and feed rate, but decreases at higher level of spindle speed. Lower thrust forces are usually obtained at smaller drill bit diameters (6 mm). Smaller drill bits require less force to advance through the workpiece because they remove less material with each rotation. As feed rate and drill bit diameter increase surface roughness increases, but it reduces when spindle speed increases. The cutting area in contact with the natural composite surface decreases with a smaller drill diameter (6mm). From the prediction result, it was confirmed that the drill bit diameter (6 mm), spindle speed (2220 rpm), and feed rate (80 mm/min) minimized the thrust force (2.65 kgf) and surface roughness (4.97µm). The error percentage for thrust force and surface roughness were 1.85% and 4.5 % respectively. The SEM research revealed that fiber pullout, matrix bonding, and matrix cracking are shown by reduced drill bit diameter, spindle speed, and feed rate. Higher SR was the outcome of increased parametric level, which revealed delamination and matrix deformation. The Prosopis juliflora fiber-based composite has attained near saturation, where the rate of absorption considerably declines as the material reaches its optimum ability of retaining water, according to the least water consumption seen at the higher exposure time of 192 hours.

Ethical Approval

This study did not require ethical approval

Consent to Participate

All authors provided informed consent to participate in this study

Consent to Publish

The author provided consent for the publication of their data in this study

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Competing Interests

The authors declare no competing interests

Data Availability statement

All data generated or analysed during this study are included in this published article.

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