INVESTIGATIONS OF DRILLING INDUCED DELAMINATION DAMAGE ON NATURAL FIBER COMPOSITES: A REVIEW

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ABSTRACT

Technological advancements for the past few decades have always progressed a little higher than the previous years, yet people constantly aim to improve the performance and efficiency of a machine through a variety of new techniques and methods.A natural composite is a substance that is a combined product of various naturally available, bio-degradable and non-hazardous substances having suitable and necessary mechanical properties thatretains the necessary mechanical properties along with drastically reducing the weight. Such materials that are tested whether they would prove to be potential replacement for the conventional metals in practice. This paper is an attempt to review parameters such as delamination and surface roughness that affect the quality of the drill in the natural fiber composites as drilling is necessary when assembling it with another part.

INTRODUCTION

The concept of the usage of these fiber-reinforced composites has risen from the story of strength in unity. The moral of the story is that a single piece of any material can be broken easily whereas when the same is grouped together, its strength multiplies. Similarly, when the composites are reinforced with layers of natural fibers, the mechanical properties attain necessary strength along with the reduction in the overall component weight. Hence, the natural fiber composites are a suitable replacement for the conventional materials and metals used in the industries [1]. This paper discusses the various research works done in this field. Researchers like Saravana Bavan et al. have researched the possibilities of the applications, properties and availability of the natural fiber reinforced composites in the country [2]. The properties of the natural fiber composite mainly depend on the volume to weight ratio of the fiber, type of arrangement of fiber layers, treatment and usage environment[3]. The composite blocks are made up through stacking of individual woven mats of fibers in a suitable matrix arrangement like wood, human bone, coconut fiber [4].

Taking a clue from this, humans attempt to replicate and manufacture their own by combining fibers together. However, conventional manufacturing techniques cannot be used in their manufacturing. So they have to be manufactured part by part, drilled and then assembled. Drilling and the surface roughness of the composite block are important parameters that drastically affect the fit and functionality of the product.The fibers are held together strongly by means of synthetic resins like poly propylene (PP), epoxy resin, etc. Studies have proved that the drilling parameters such as feed rate, thrust, and drill geometry have major impact on the fiber composite [4-5]. According to a research, sponsored by the US department of Energy (DOE), natural fibers with having major mechanical properties are discussed below in table 1.

Fibers	Elongation	Tensile strength	Elastic modulus	references
Jute	1.5-1.8	393-773	26.5	9a
Hemp	2-4	690	70	10a

Ramie	3.6-3.8	400-938	61.4-128	10b
Coir	30	593	4-6	11
Cotton	7-8	400	5.5-12.6	9a,9b
Flax	2.7–3.2	500–1500	27.6	10a
Kenaf	1.6	930	53	10a
Sisal	2-2.5	511-635	9.4-22	10b
soft woodcraft pulp	4.4	1000	40	11

Table- 1 Fiber Properties

Because of the poor compatibility between the resins and the natural fibers, the fibers must be suitably modified by physical or chemical treatments as discussed below in table 2.

TREATMENTS	
PHYSICAL	CHEMICAL
Stretching [9]	Esterification [17]
Calandering [10]	Isocynate reaction [18]
Thermal treatment [11]	Triazine reaction [19]
Corona discharge [12,13]	Reaction with organosilane [20]
Mercerization [14]	Reaction with biodegradable coupling silane [21]
Impregnation [15, 16]	

Table- 2 Types of treatments

REVIEW ON DELAMINATION

To manufacture a product made up of composites, several parts have to be combined through fasteners whose primary necessity is a drilled hole. The quality of the drilled hole plays a major factor for delamination prior or post usage, leading to the component's failure. Therefore, drilling has become a keen research area in the composites. Pramendra Kumar Bajpai et al. found that drilling a composite is totally different from drilling metals as when drilling a composite made up of layers of polymer and fiber, that are distinct, the drill bit can cause potential damage to the drilled hole. This damage primarily depends upon the thrust force and torque generated during the drill. These defects can be minimized by altering the parameters such as feed rate, cutting speed and drill geometry, which play a major role in the hole geometry [30].

Tsao investigated the parameters that have maximum influence in the quality of the drilled hole. The study was conducted with a step-core drill in drilling of carbon fiber-reinforced plastic laminates and the study concluded that the diameter and feed rate have a major influence in the drill performance [31]. Paul et al. attempted to vary the drill point geometry to study the drill hole quality. There was a 40% reduction in thrust force and torque individually using optimized helical drill. Thus when the thrust force is reduced, delamination is reduced too [32]. Franke examined the influence of drill bit's cutting edge on the hole quality. During the experiment, it was found that feed rate was found to be a major determining factor for the delamination [33]. Mohan et al. conducted an experiment using taguchi optimization methodology and tried to optimize the existing drill parameters like speed, feed rate and drill size. It was found that the speed and drill size have a significant effect on thrust force generated during the drilling process [34]. Athijayamani et al. experimented using HSS drill bit on roselle/sisal fibers using Regression Models (RM) and Artificial Neural Network (ANN).

The study proved that the ANN model is more accurate than RM in terms of thrust force and torque predictions in natural fiber composites [35]. A.A. Abdul Nasir, A.I. Azmi et al., in their paper [36], have found that the spindle speed plays a major role in affecting the maximum residual tensile strength of a composite fiber. He says when the spindle speed decreases, then the probability of delamination to occur is maximum. Thus optimum spindle speeds have to be maintained. However, the delamination and hole quality reduces and improves respectively for low spindle speeds in a flax fiber composite using a twist drill and step drill.

Jayabal(2011) has studied the nonlinear mathematical equations of thrust force, torque and tool wear were developed to correlate the important machining parameters in drilling of coir–fibre reinforced composites. The L9 orthogonal array was developed for analyzing 3 variables and 3 levels in each variable. The recordings were discussed in the below table

SI. No	Drill Bit Diameter(mm)	Spindle Speed(rpm)	Feed Rate (mm/rev)	Thrust Force(N)	Torque(Nm)	Tool Wear(mm)	Chip Formation
1	6	600	0.05	50	2.02	0.07	C
2	6	1200	0.35	88	1.56	0.15	D
3	6	1800	0.20	58	2.94	0.20	CD
4	8	1200	0.20	52	2.30	0.16	C
5	8	1800	0.05	55	3.45	0.20	D
6	8	600	0.35	32	1.02	0.03	CD
7	10	1800	0.35	49	3.92	0.25	C
8	10	600	0.20	69	1.56	0.12	D
9	10	1200	0.05	39	2.25	0.21	CD

Table 3- Recorded values in L9 orthogonal array.

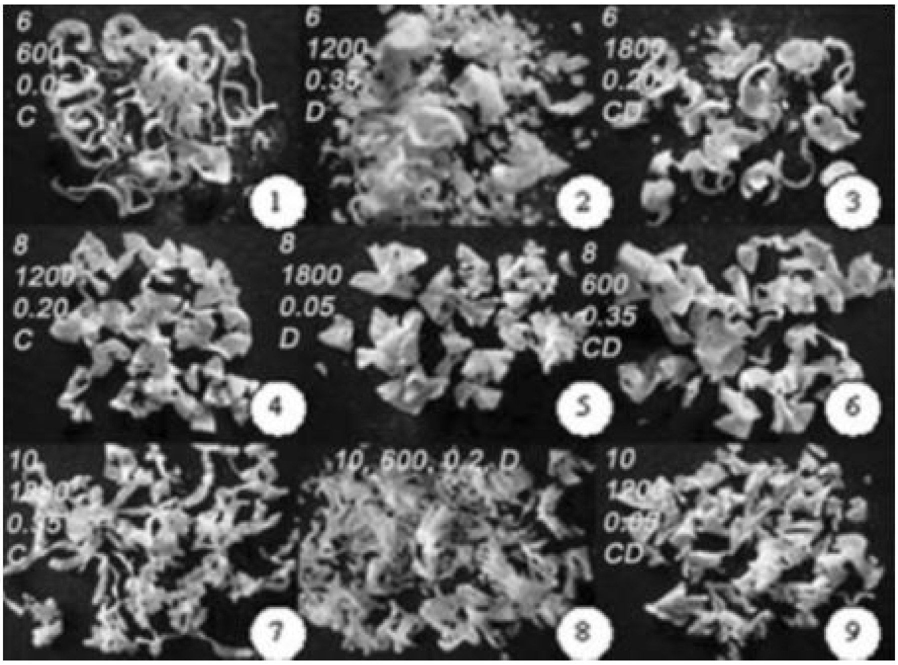
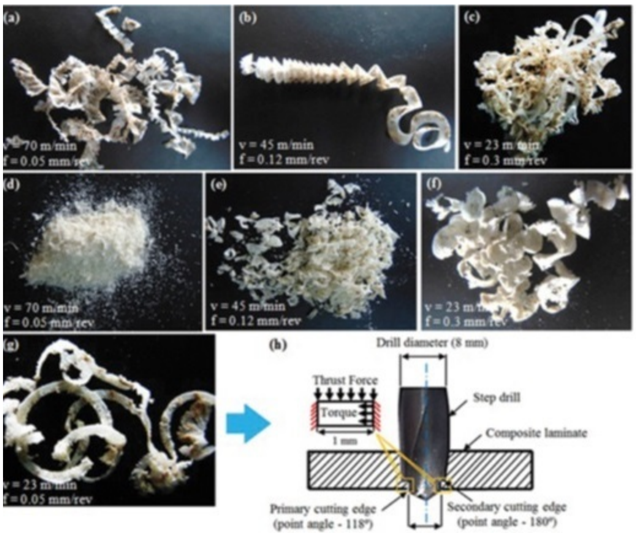


Fig- 2 L9 orthogonal array [37]

In the context of sisal fiber, it can be said that it has high strength and modulus, easily available, and is renewable [38, 39]. The constituents of sisal fiber are 78% cellulose, 10% hemicellulose, 8% lignin, 2% waxes, and about 1% ash [40]. The high content of cellulose brands sisal fiber as one of the superior natural fibers. Moreover, the cost of sisal fiber is substantially less than the synthetic fibers (five hundredth of the carbon fiber and one ninth of the glass fiber [41]. Therefore, the work of Kishore Debnath (2014) is an earnest endeavor in the area of drilling behavior of natural fiber-reinforced composite laminates. Fundamental differences have been observed in the selection of optimal drill geometry for drilling of sisal-epoxy and sisal-PP composite laminates. [42]

Results

Materials: Unidirectional sisal fibers of 250–400 mm in diameter were used for fabricating the composite laminates.Drilling Parameters: The drilling of composite laminates was performed at five different levels of feed (0.05, 0.08, 0.12, 0.19, and 0.3mm=rev.) and at spindle speed of 900, 1800, and 2800 rpm under dry condition.



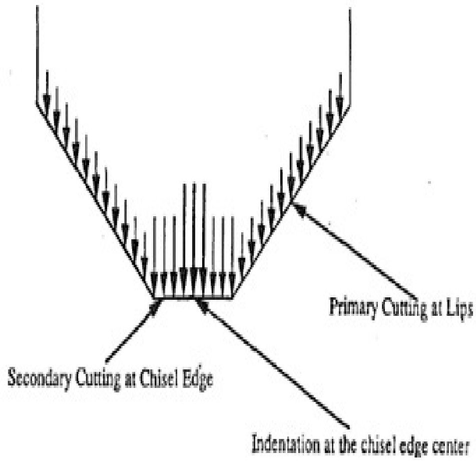
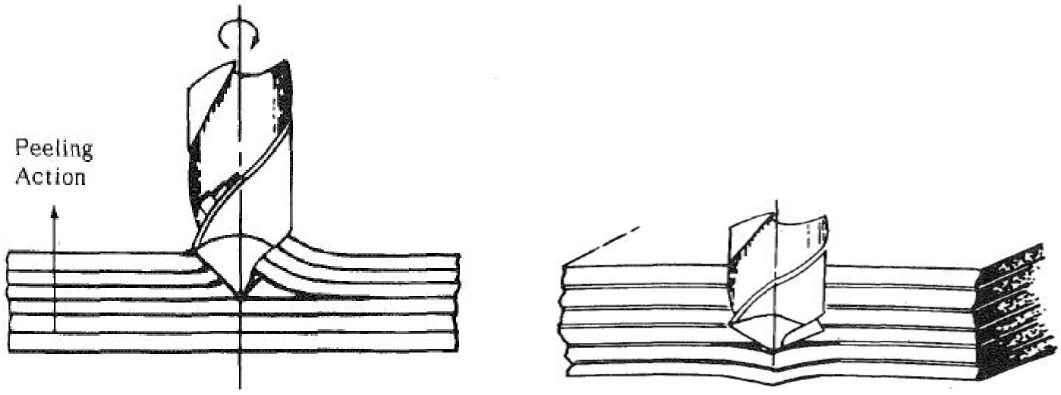


Fig- 3 chip formation[42]Fig- 6 Drilling forces due to drill bit [46]

No entry and exit delamination were observed during drilling of sisal-epoxy and sisal-PP laminates. But, damage in the form of fiber pullout, debonding between fiber and matrix, and smearing of polymer were observed.[42].Other major parameters that contribute to the delamination is the peel up and push out. This was studied by H.HoCheng [43]. The delamination property occurs both at the entrance as well as the exit and they are called peel-up at entrance and push out at exit [43].



(a)Peel-up delamination at entrance [43] (b)Push-out delamination at exit [43]

Fig- 5 Mechanical Drilling Characteristics [43]

The lower axial thrust creates less delamination [44]. It shows `that glass/epoxy composites possess stronger resistance to delamination than graphite/epoxy composites. This behavior is exactly predicted, in which materials with higher fracture toughness (glass/epoxy) are expected to delaminate at larger thrust than materials with lower fracture toughness (graphite/epoxy).[44] A rapid increase in feed rate at the end of drilling will cause cracking around the exit edge of the hole.[45]. D.C.H. Yang [46] conducted experiments on unidirectionally laid composites. He depicted the forces that act on the composite by the drill bit pictographically that helps us understand the peel up and push out, effect of chisel edges and flute uses in removing the drilled bits.

Thus D.C.H Yang has proposed a model to predict the thrust forces in any unidirectionally laid laminate composites. He found that the thrust forces increase in the absence of the chisel edge and that the thrust force reduces with reduce in the chisel length (mm).The chisel edge has been identified as a major contributor towards thrust force with minor variations due to point angle [46].

CONCLUSION

The main objective of this work is to study the effects of delamination in the drilled holes of natural fiber composites. For any product made out of composite, to work properly, it is very much necessary for it to maintain its properties throughout its manufacturing, assembly and working life periods. However hard the composites may be, it is not possible for us to visually tell if it will withstand all kinds of forces of manufacturing operations. Thus selection of appropriate manufacturing parameters is necessary. Only then, maximum and optimum utilization of the composites are possible.

Many experiments were discussed, which helps to measure, analyze and evaluate the quality of the drilled hole. From the above discussions, it can be concluded that the optimum ranges to obtain the smoother surface roughness is using a twist drill having 22.4 and 43 N forces and the optimum ranges to avoid delamination is by having a twist drill 8mm dia at 600rpm, 0..5mm/rev having torque 1.02N and thrust force 32N. This enables the composite to be drilled without getting delaminated.

Further the peel up and push out delamination may be reduced through a pilot drill followed by the primary drill. There is further scope for research in analysis of surface roughness in natural fiber composites and hybrid fiber composites.

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