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Drilling of glass fibre reinforced polymer /nanopolymer composite laminates: a review

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Abstract:

Over the last decade, the use of polymeric composite material has increased considerably, and as a result, focus on machinability of such material has also increased. In order to fabricate structural components of FRP to near-net shape, machining of FRP is necessary. Drilling is the most frequently practised machining process for fibre reinforced polymeric composites in industry owing to the need for component assembly in mechanical structures. The various parameters during the drilling operation that might influence the drilling factors and material damage have been identified while working with commercial composites. The present study is an attempt to precisely review on drilling of current state glass fibre reinforced polymers as well as nanopolymer composite laminates. Specifically, the influence of machining parameters, tool geometry, tool materials and tool types on the cutting force generation and delamination mechanisms.Based on the comprehensive literature survey from the past few years, it is noticed that although many works have been done to characterize the drilling behaviour of family of FRPs but there have been minimum or limited research concerning to nanopolymer composite drilling andon the effect of fillers on machining characteristics of FRPs. The effects of fillers are going to have on drilling behaviour of reinforced plastics have not been reported and needs to be investigated in order to fully realize their application potential. This has led to a partial understanding of the cutting mechanics activated in machining/drilling of nanopolymer composites. Therefore, some key contributions such as experimental and numerical studies are urgently demanded to address accurately various projections in drilling of nanoparticle reinforced FRP composite laminates.

Keywords: Drilling, Delamination, FRP laminates, Nano polymer composite laminates, Cutting forces

1. INTRODUCTION

Fiber-reinforced composite materials are finding increased application in many engineering fields such as automobile, aerospace, sport goods, marine industries, etc. The basic initiative behind the learning of FRP composite laminates mainly comprise glass fiber reinforced polymer composite materials (GFRP), carbon fiber reinforced polymer composite materials (CFRP) and nanopolymer composite materials and their applications are based on the possibility of using materials with definite characteristics and specific properties that are not found in any of the raw materials. [1].

Among the fiber-reinforced composite materials, glass fiber reinforced composite materials (GFRP) find an increased application due to their superior advantages such as high specific strength, light weight, high specific modulus of elasticity, corrosion resistance, etc. [2]. Various industries; such as auto- motive, aerospace, marine and oil industries, have already started the utilization of nanocomposites in their structures. The most recent commercial aircraft designs have proposed a reduction in weight about 50% by replacing the primary structural components with fabricated nanopolymer composites. In order to achieve the reduced fuel consumption and better passenger comfort goals of these future commercial aircraft design innovations the use of light weight and elevated strength composites are required [3].

Although most of the composite products are made to a near-net shape, subsequent machining is required for assembly purposes. Drilling is one of the most important, frequently practiced, and unavoidable machining operation for components used in FRP composite structures. Intricacy in structures necessitates hole generation to facilitate assembly. The mechanism of drilling composite materials has been recognized as a process fundamentally different from that of homogenous metal removal. The diverse properties of the fiber and the matrix combined with fiber orientation have a significant effect on the drilling process. During drilling, the fibers take a high proportion of the load, which prevents uniform plastic deformation as normally observed during chip formation in metal cutting [4,5].

Many researchers have reported various problems related to drilling of FRPs, owing to their material in-homogeneity and anisotropy [5-10]. The major problems are excessive tool wear and workpiece material or quality anomalies. Among the various work-material related problems, delamination in drilling FRPs has been recognized as one of the major problems by most of the researchers, since it affects the hole quality rigorously. It is regarded as a resin or matrix dominated failure behavior or phenomenon [11]. It is found to be much significant or severe at the bottom side of a workpiece or at the hole exit periphery, called “push-out” delamination (hole exit delamination). With that reason, about 60% of the drilled holes on composites are rejected at the initial stage only [12].

Also, the drilling of FRP composites have several undesirable effects such as spalling, edge chipping, macroscopic pitting, fiber breakage, debonding, fiber pullout, crack formation, thermal damage, fuzzing, stress concentration, matrix crazing along with delamination [13]. Therefore, in order to improve the product performance and structural integrity of machined holes, the various material defects have to be trim-down by proper selection of cutting parameters, tool geometries, tool types and cutting conditions [14,15]. Nevertheless, the structural integrity of the materials also strongly depends upon on fiber matrix interfacial interactions, fiber orientations, cutting directions and tool wear.

Mohan et al. [16] have performed delamination analysis in drilling process of GFRP composite materials. The study investigated the factors and combinations of factors that influence the delamination using Taguchi's methodology, and the optimal machining condition resulted in minimum delamination was found. Khashaba [17] did experiments on delamination in drilling GFR-thermoset composites. He has investigated the influence of drill and material variables on thrust force, torque, and delamination in drilling GFRP composites. He did extensive studies on different E-glass composites. He has developed a simple accurate technique to measure the delamination size. Latha and Senthilkumar [18] studied the delamination in drilling of GFRP laminates. They developed a fuzzy rule-based model for predicting delamination in drilling of GFRP laminates.

Zhang et al. [19] have investigated the spalling, fuzzing exit sub-surface deformation defects during drilling of unidirectional as well as multi-directional CFRP laminates with HSS twist drill. Spalling and fuzzing are considered as the major exit damage mechanisms during drilling of FRP composite laminates and these damages increase with an increase in feed rate and decrease in spindle speed. Spalling at hole exit is usually a severe damage and it is bigger for UD-CFRP laminate as compared to multi-directional CFRP laminate under the same drilling conditions. Hocheng and Tsao [20] have presented a prediction and evaluation scheme of delamination factoring drilling of composite materials by using twist drill, candle stick drill, and saw drill. They have used Taguchi's approach and analysis of variance (ANOVA) for analysis. In this work, ultrasonic C-scan was used to examine the delamination. Arul et al. [21] haveutilized acoustic emission technique to improve the quality and surface integrity of the machined hole during drilling on woven glass fabric/epoxy composite laminates. The effect of cutting parameters on axial force, flank wear and their influence on the hole shrinkage was monitored and correlated with AE parameters.

Davim et al. [22] carried out experiments on GFRP composite materials and have noticed that the feed rate is the main parameter that affects the thrust force. They used ''Brad & Spur'' drill point, which produces high-quality holes compared to the conventional drill.Palanikumar [23] has used a fuzzy logic rule–based model for the prediction of surface roughness in machining glass fiber reinforced plastic (GFRP) composites. He has established a relation between the cutting parameters and surface roughness parameters in turning of GFRP composites by PCD (Poly crystalline Diamond) tool. Bhatnagar et al. [24] found that thrust force and torque influence the delamination and related damages in composite materials.

In general, when the drill tool comes in contact with the FRP composites, the drill chisel edge generates a nominal thrust force in the axial direction and subsequently initiates the surface deformation due to the frictional rubbing action of tool and work-piece [25,26]. This deformation can remain the same upto the last two piles of composite laminates and increases drastically for further drill extent due to the smaller uncut chip thickness, lower resistance to deformation and stiffness. At this instant, the exit side of the laminate undergoes severe damage of matrix and initiation of crack propagation resulting poor surface integrity [27,28]. Also, the tribological interactions between tool and workpiece are the reasons for sub-surface deformation of the composites and these thermo-mechanical mechanisms can be reported in the form of tool wear [29]. The chief tool wear mechanism during drilling on FRP as well as nanocomposite laminates is abrasion and it is generally occurred on rake and flank face of the tool cutting edge. Therefore, it causes severe abrasive wear on the flank face resulting poor structural integrity and long-term performance deterioration of the machined surface [30].

Inoue et al. [31] inspected the effect of tool wear on the sub-surface deformation in drilling of small diameter holes of GFRP composites. Based on experimental results, it was concluded that higher flank wear occurs at lower feed rates and larger cutting speeds. Abrao et al. [32] have made an extensive literature on drilling of FRP composites. Aspects such as tool geometry, machining parameters and their influence on thrust force, torque and delamination are examined in the review. Liu et al. [1] presented a review article on mechanical drilling of composite materials such as FRP (CFRP, GFRP) as well as fiber metal composite (FML) laminates. This review paper also included grinding drilling, Vibration-assisted twist drilling (VATD) and high-speed drilling (HSD) operations of both FRP and FML composites.

Now-a-days, the mechanical, wear and other properties are enhanced dramatically by reinforcing various kinds fillers with FRP composites. These secondary reinforcements are called nanofillers; namely carbon nanofibers (CNFs), carbon nanotubes (CNTs), polyamide 6, Polypropylene-Silicon, Graphite and Graphene etc. When silica particles are added into a matrix, they play an important role in improving electrical, mechanical and thermal properties of the composites. Epoxy filled with smaller alumina trihydrate particles show higher fracture toughness. The filler particle size is being reduced rapidly and many more recent studies have focused on how single particle’s size affects mechanical properties [33–37]. A typical layout of classification of composite materials is shown in Fig 1.

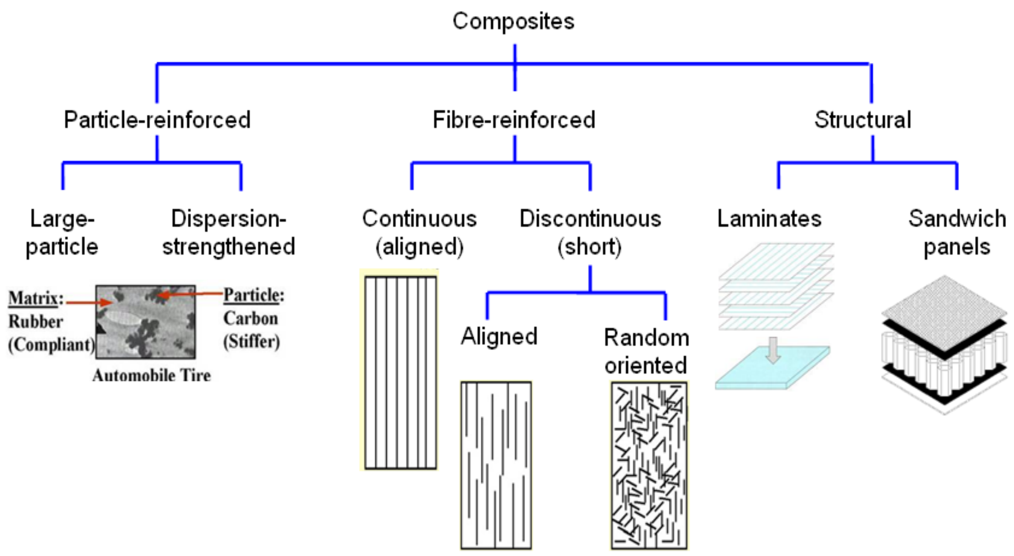


Fig.1- A typical classification of composite materials according to reinforcement format

Yamamoto et al. [38] concluded that the structure and shape of silica particle have significant effects on the mechanical properties such as fatigue resistance, tensile, and fracture behavior. Nakamura et al. [39] reported the effects of size and shape of silica particles on the strength and fracture toughness based on particle matrix adhesion and also found an increase in the flexural and tensile strength as the specific surface area of particles increased. Nicolasis and Nicodemo [40] studied the effect of particle shape on tensile properties of glass thermoplastic composites. Patnaik et al. [41] reported that the mechanical properties of polyester based hybrid composites are highly influenced by the type and content of the filler materials. Glass/vinyl ester composites with fillers are used in laminates where high degree of moisture resistance is chemically corrosive environments such as chemical tanks and in structural desired [42]. The vinyl ester resins are less susceptible to water degradation than polyesters because of the reason that they have fewer ester groups. Vinyl ester composites are generally preferred for moderate temperature applications because of its good corrosion resistance to strong acids, bases, and salt solutions, greater tolerance to pressure fluctuations and mechanical shock, good adhesion to the glass fibers, rapid curing, and superior creep resistance than the polyesters and epoxy resins [43].

Starost and Njuguna [44] reported on the effect of mechanical drilling on nanocomposites laminates. The effect and influence of various drilling parameters on delamination and nano-sized particles have been discussed. Davis et al. [45] concluded that amino functionalized single-walled CNTs/CFRPs and fluorine doped single-walled CNTs/CFRPs nano composite laminates exhibit good improvement in tensile strength, stiffness and fatigue durability compared to non-functionalized composites under tension–tension and tension–compression loadings The multi-walled CNTs/CFRP composite laminates cured by microwave process was prepared to prevent delamination and drilling ablation and have been compared against normal conventional thermal cured composite without MWC- NTs [46]. The fiber reinforced composite laminates thermal conductivity has been increased drastically with the addition of nano-filler/micro-filler; namely, MWCNTs, DWCNTs [47].

The effect the fillers are going to have on the drilling behavior of reinforced plastics has not been reported and needs to be investigated in order to fully realize their application potential. The present research endeavor is an attempt to provide a comprehensive review of drilling on FRPs as well as nanopolymer reinforced composite laminates. Although, many research works have been done to characterize the drilling behavior of family of FRPs but there have been minimum or limited studies on the effect of fillers on the machining characteristics of FRPs. Also, there is a need to continue research in the field of nanocomposite drilling especially nano-particle (CNF/CNT) reinforced FRP composites. As specified, nanocomposites are newly introduced materials in the commercial industry and their enhancing properties are expected to behave differently during drilling operation. In addition to that the influence of drilling variables such as cutting parameters, tool geometry, tool types and tool materials on the thrust force, torque and delamination in drilling of nanopolymer composites is compulsory for better understanding of machinability and to fully realize their application potential.

2. DRILLING OF COMPOSITE

2.1 Drilling studies on conventional FRP composites

Drilling is the important hole-making operation in the engineering field. Among various types of drilling operations on composite laminates conventional drilling is performed most frequently. The other operations like vibration assisted drilling, high speed drilling are also used and produces superior quality drilled holes along with high efficiency [1]. The research on development of mechanical drilling on composite materials focuses mainly on drilling mechanics, drill tool geometry and material, tool types, delamination mechanisms and its preventing approaches, cutting force, and tool wear, etc. In conventional drilling of composite materials, hole quality is the main priority. Hole quality is determined by surface finish, roundness, hole diameter, etc. In addition to surface roughness and roundness error, the delamination factor is also a measure of quality. Delamination is a damage phenomenon that occurs due to the anisotropy and brittleness of composite materials.The delamination factor (F_d) is determined by the ratio of the maximum diameter (Dmax) of the delamination zone to the hole diameter (D). The scheme is shown in Fig. 2.

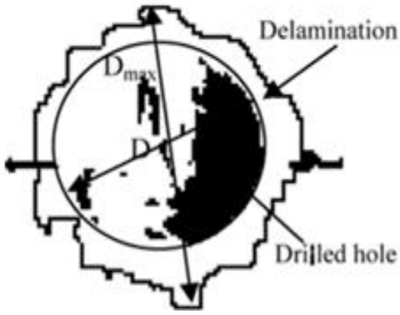


Fig.2 – Scheme of delamination factor

Based on the review on experimental analysis, it has been found that during the drilling operation, the important cutting parameters that affect the delamination are spindle speed and feed rate. The input parameters such as cutting speed, feed and point angle of twist drill, tool types, tool materials, type of drilling operation directly affect the drilling induced delamination on FRP composites. The following observations are noticed from literature survey on drilling in composite laminates [48-51].

Delamination tendency increased with the increase of twist drill point angle. Special drill bits (straight-flute drill bit, brad point drill bit and step drill bit) with larger feed rate shows without delamination compared with the twist drill bit. Carbide coated and diamond coated tools deliver better results in terms of tool wear and tool life during drilling on composites. Generally, the minimum delamination defect on composite materials occurs at low feed rates with high cutting speeds.

The value of delamination factor can be expressed as follows [22]:

$$F_d = \frac{D_{max}}{D} \qquad (1)$$

Delamination is one of the major problems accompanying drilling of composite laminates. It occurs in the interply region and is regarded as a matrix or resin-dominated failure behavior. Experimental observations have shown that delamination occurs both at the exit as well as at the entrance, thus involving two distinguishable mechanisms that are responsible for delamination in each case. They are called push-out at exit and peel-up at entrance. Delamination at exit is more serious and more frequently occurring than that at entry. It appears as peeling away of the bottom ply or plies, and the width of the delamination zone is related to the thrust force during drilling [52].

In addition to the cutting parameters, tool geometry, tool types, etc., the work piece constituents, laminate orientation ($0^0/0^0/0^0/0^0$, $45^0/45^0/45^0/45^0$, $0^0/45^0/0^0/45^0$, $45^0/0^0/45^0/0^0$, $0^0/0^0/45^0/45^0$ and $45^0/45^0/0^0/0^0$) also effect the delamination in drilling of composites [53,54].Table 1 shows the detailed range of cutting conditions during drilling on CFRP and GFRP composite laminates.

Table 1: Typical drilling parameters for drilling of composite material

Workpiece Material	Tool Material	Hole Diameter (mm)	Material Thickness (mm)	Cutting Speed (m/min)	Feed Rate (mm/rev)
Graphite-epoxy	Carbide	4.85	6.35	60.9	0.0254
Glass-epoxy	HSS	--	12.5	15.0	0.028
Glass-epoxy	HSS	8	12	40.2	20-460 mm/min
Carbon-epoxy	Carbide	3	10	33	0.05

2.2 Drilling studies on nanopolymer composites

As nanoopolymer composites are relatively newly introduced materials, there have been very few or limited studies performed on the drilling of nanocomposites. Minimum details are available on the development of nanocomposites, property evaluation, processes parameters, drilling defects and thermal damage in nanopolymer composites drilling as per existing literature, [55–59]

Table 2: Drilling operations typically employed for nanopolymer composite laminates

Material	References	Remarks
CFRP/CNF, Hybrid carbon/glass fibre, polypropelene/ CNT, PA6/CNT, polypropelence-silicon, Si_3N_4/epoxy	Irfan et al. [79]; Sophia Sachse et al. [75]; Bello et al. [69]; Paul et al. [68]; Tan et al. [81]; Li et al. [46], Starost and Njuguna [44]; Gowda et al [82]; Baker et al. [61]	Spindle speed <1500 rpm and feed rate <0.1 mm/min. Adjacent to the uncoated HSS drill, other coated drills such as carbide coated, CBN coated. Diamond coated, and diamond like coated drills are also used in drilling of nano-polymer composites. A combination of high spindle speed and low feed rate reduces delamination and circularity error.

Paul et al. [60] adapted acoustic emission technique for online monitoring of drilling induced delamination during drilling on CNF reinforced nanocomposites laminates.Baker et al. [61] used the drill tool coatings to reduce the wear resistance during drilling on nanocomposites. Li et al. [46] have experimented microwave curing process to minimize delamination and drilling ablation in drilling of carbon nanotube/carbon fiber reinforced epoxy composites. The experimental results showed that the drilling induced delamination of microwave cured nanocomposites has decreased and interlaminar fracture toughness increases upto 66% compared to normal cured composites. The availed literature on drilling of nanocomposite laminates and its drilling conditions are given in Table 2.

3. DRILLING PROCESS

In drilling operation, the input process parameters are cutting speed, feed rate, depth of cut, tool geometries, tool types and tool materials etc. which affects the output process parameters such as thrust force, torque, tool wear, delamination, surface roughness and other drilling defects. Therefore, it is required to choose the proper process parameters for obtaining the best performance on the drilling operation i.e. best hole quality, that means minimum damage of the machined components and satisfactory machined surface. Fig. 3shows the schematic diagram of drilling process parameters which are affecting the drilling of FRPs.

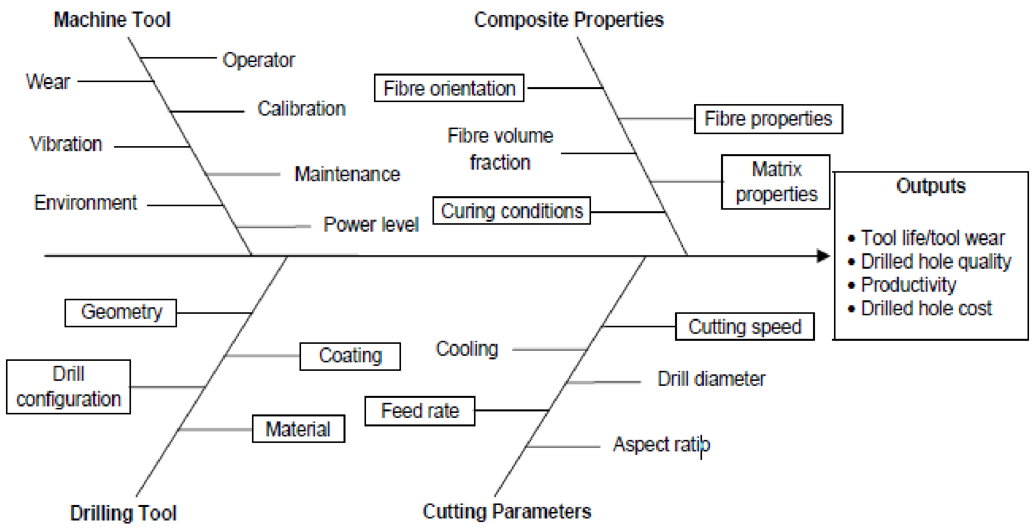


Fig.3-Fishbone diagram detailing factors affecting the drilling of FRPs

4. MECHANICS OF DRILLING COMPOSITE MATERIAL

The thrust and torque applied on a bit during drilling operations depend on speed, feed rate, tool geometry and tool wear while drilling conventional as well as nanopolymer composite laminates. Experiments [62] showed that thrust increases steadily until a constant value corresponding to steady drilling through the thickness of the laminate is reached, and is followed by a sharp drop as the tool exits the opposite side (Fig. 4).A sharp decrease in normal force as the bit enters the work piece is always associated with the introduction of delamination by mechanical action of the tool peeling up the top layer of laminate. Delamination of the top layer can also be produced by high thermal stresses generated by drilling, but, in that case, no discontinuities are observed in the normal force history.

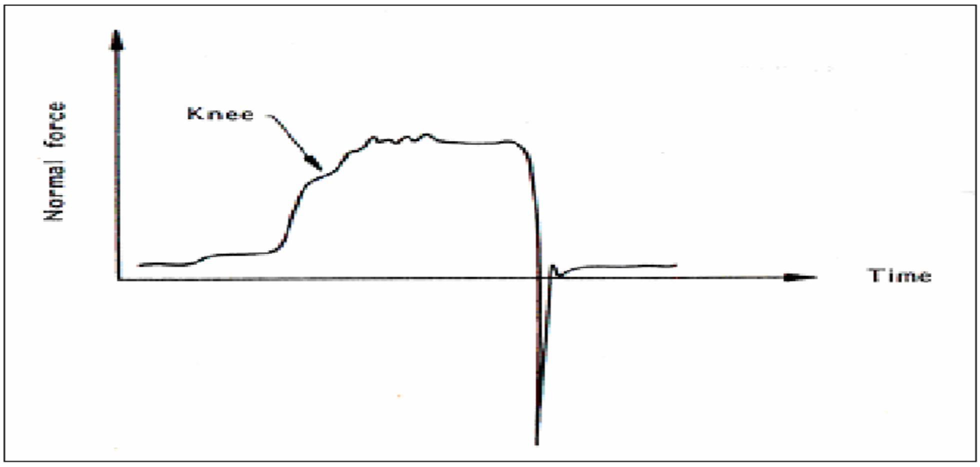


Fig. 4 - Typical axial force history during drilling of composite laminates

Delamination near the exit sides is introduced when the tool acts like a punch separating the thin uncut layer from the remainder of the laminate. This action is associated with an almost instant drop in normal force from its steady value down to zero. Delamination can be greatly reduced or eliminated by reducing feed rates near the end and using backup plates. During drilling torque increases rapidly until the cutting edges of the tool are completely engaged and then increases linearly until a maximum value is reached, followed by a slight drop after hole completion. (Fig.5)

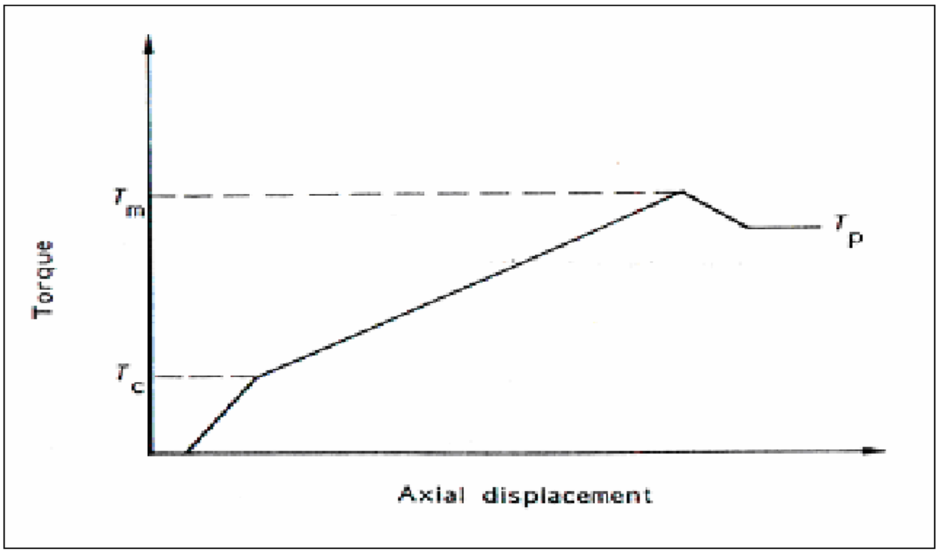


Fig 5- Variation of torque during drilling

As drilling progresses, the tool is in contact with the side over an increasing area so that frictional forces at the interface create increasingly higher resistant torque. [63] After complete penetration has occurred only a small decrease in torque is observed which indicates that friction is the major contribution to total torque. Maximum normal force and maximum torque both increase very significantly with the number of holes drilled.

5. DRILLING PARAMETERS

5.1 Effect of drilling parameters on thrust force, torque and delamination

The cutting parameters such as cutting velocity and feed rate, tool geometry, tool types and tool materials have shown greater effect on the thrust force, torque and delamination while drilling conventional as well as nanopolymer composite laminates. The cutting forces decrease with increasing cutting speed and increase with higher feed rate, drill size and fiber volume fractions. In drilling of carbon/epoxy composites the torque, thrust force and delamination factor depends directly on the feed rate and tool geometry [26,29].

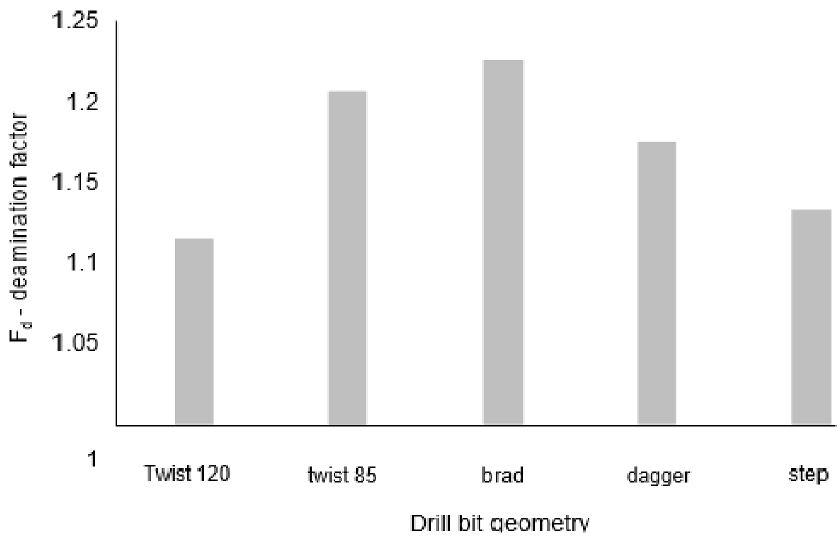
Palanikumar et al. [64] have reported from the experimental and analytical results that the low feed rate and drill diameter leads to increase the thrust force, whereas the increase in the spindle speed does not show any disparity. Velayudham et al. [65] have conducted experiments on drilling and have reported that the thrust force increases at different rates depending on the contact between the workpiece and the drill. Karimi et al. [66] examined the parameters that influence the thrust, hole quality, and strength offiber reinforced composites. This article illustrates the impact of machining parameters on the thrust force in drilling polypropylene laminates. Cutting parameters and thrust force are related using the response surface method. Phadnis et al. [67] experimental study reported that low feed rates (<1500 mm/min) and high cutting speeds (>600 rpm) are the best cutting parameters for drilling on carbon/epoxy laminates. Paul et al. [68] have experimented with the cutting parameters range of 500–1500 rpm in spindle speed and 0.02–0.08 mm/rev in feed rate for minimum drilling induced delamination and surface roughness during drilling on CNF reinforced CFRP nanocomposite laminates. Specifically, the lower feed rate (0.02 mm/rev) and higher spindle speed (1500 rpm) gives the better thrust force and torque values. Bello et al. [69] have done a series of drilling experiments on advanced CNT hybrid composites at a spindle speed range of 725–1325 rpm for optimum cutting conditions. The spindle speed of 1015 rpm gives the lower thrust force and torque values.

In general, statistical techniques such as ANOVA, regression analysis etc. are used to establish an empirical relationship between the drilling parameters (feed rate, spindle speed, drill diameter and fiber volume fraction) and cutting forces in drilling of FRP composites. Optimizing the machinability characteristics like feed rate and spindle speed on nanopolymer composite drilling is an essential task, to reduce the drilling defects, thrust force, surface rough- ness and tool life [70,71]. Hence, the cutting parameters such as cutting speed and feed have greater influence on the thrust force, torque and delamination during drilling on conventional/nanopolymer composite laminates.

Therefore, in order to produce defect free holes, the process of drilling on nanopolymer composite laminates needs to be taken care of.

5.2 Effect of tool geometry on thrust force, torque and delamination

The various drill tool geometries like drill tool diameter, helix angle, point angle, chisel edge, rake angle and web thickness have greater influence on thrust force and torque. The drill bit angle highly affects the machining forces and drill hole quality of the composite laminates. Fig. 6 shows the delamination factor value for different drill tool geometries. During drilling of GFRP/Epoxy composites, the drill tool geometry and tool material highly affects the cutting forces and material damage. Four drills (EDP27199, A1141, A1163 and A1167A) with different drill geometries and materials and various cutting parameters were used to test the composite for defect free holes in drilling [72]. Velayudham and Krishnamurthy [73] have done a series of drilling experiments to study the influence of carbide drills with different point geometries on thrust force and delamination of polymeric composite laminates.



Experimental investigation results showed that tripod drill performs better cutting forces compared to other drill geometries and the critical thrust force observed when feed rate was 0.1 mm/rev, above that there was a rapid increase in thrust results. The drilling experiments using coated tungsten carbide drill (ratio drill) on Glass Fiber Reinforced Epoxy (GFRE) composite rods have shown better machinability compared to regular twist drill. The new drill geometry called ratio drill was used to predict the machining parameters, flank wear, surface roughness and circularity errors [74]. Sachse et al. [75] have performed Experiment by choosing a 10 mm diameter drill bit for drilling on PA6 nanocomposites under controlled environment for the evaluating of emission of particles.

Therefore, by selecting the proper cutting tools geometry and its nomenclature gives the enhanced cutting forces and minimum material damage in drilling of FRP as well as nanocomposites laminates.

5.3. Effect of tool types and tool materials on thrust force, torque and delamination

Various types of drill bits and drill bit materials significantly influence the thrust force, torque and delamination. The distinct conventional uncoated cemented carbide drills exhibit a complete analysis of push-out delamination and drilling load profiles while drilling of GFRP composite laminates. Based on the experimental and analytical results, it was concluded that specialized drill tools reduced the drilling thrusts for the whole range of machining parameters compared to the conventional drills and also the magnitudes of push-out delamination damage were noticeable [76]. Along with the twist drill, the effects of different types of drills such as core drill, step drill, saw drill and candle stick drill have exhibit a major impact on the critical thrust force and delamination. In case of a saw drill, the size of the delamination zone is dependent on the thrust force applied on the FRP composite laminate. At high thrust forces, the size of the delamination zone is equal to the drill diameter, which is the minimumpossible delamination in case of a composite material. Also, when the diameter of the saw drill is considered to be zero, its behavior is analogous to twist drill with zero drill diameters or with infinite delamination zone. In case of a candle stick drill with zero circular load, i.e. no torsional load on the drill bit, the working is the same as that of a twist drill with a point load at the centerline of the drill. Also in cases where the drill centerline load is zero, this drill is analogous to saw drill. This is as the geometry of a saw drill does not accommodate for centerline loads [20,77,78]. Fig. 7 illustrates the thrust force variation related to the feed rate for different drill tools.

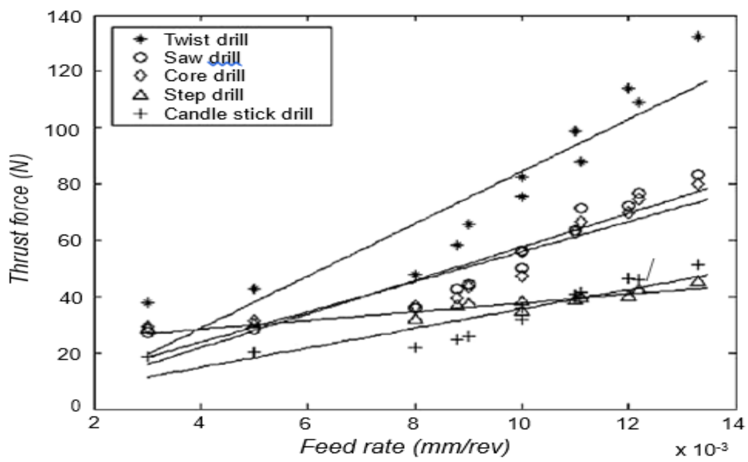


Fig. 7 - Graphical representation of the thrust force variation related to the feed rate for different drill tools [78].

Along with the standard drill tools, the newly micro coated tools such as PCD tools, CBN coated tools, diamond like coated tools, etc. were also used to acquire good surface finish of the drilled holes with less damage [79]. Irfan et al. [80] have employed a special type of angle drill of 10 mm diameter in drilling of Polyamide 6 and Polypropylene-Silicon Composites for the estimation of release of nanoparticles.

In addition to the tool geometry, tool types and tool materials also play an important role in drilling of FRP and nanocomposite laminates. The cutting forces, drilling delamination and other induced defects were minimized by the suitably selecting the drill tool types and materials.

6. CONCLUSION

It is really important to conceptualize and develop new materials for satisfying the stringent design requirements of the latest engineering applications. The materials being developed should not only be characterized for their physical, chemical, and mechanical properties, but adequate attention should also be given to their manufacturing properties. The drilling studies would play an important role in the design of materials. The delamination, surface roughness and other quality criteria of the drilled hole wall are important factors for selection of the type and quantity of fillers to be added for improving the properties composite laminates. It is important to note that in order to realize the complete potential of the novel materials being developed, a comprehensive characterization (including the manufacturability) is necessary.

In this paper, the work exhibited here referred more to the study of composites with a polymeric matrix reinforced with glass-fiber/nanopolymer composites laminates. In machining of GFRP composites apart from the feed rate, drill diameter, and spindle speed also influence the delamination factor and surface roughness. The factors like workpiece and tool material combination and their mechanical properties, quality, and type of the machine tool used, auxiliary tooling, and lubricant used and vibration between the workpiece, machine tool, and cutting tool also affect the quality of drilled holes. If proper cutting conditions are adopted, the quality of holes can be improved in drilling GFRP composites.

The mechanical drilling of nanopolymer composite laminates differs extensively in many aspects from drilling of conventional composite laminates. mainly including drilling forces, drill tool geometry, drill tool types and materials, drilling induced delamination and its inhibiting approaches, subsurface deformation, surface roughness, and tool wear, etc. In addition to that optimization of machining parameters, drill tool geometry and tool types are also investigated.

Generally, composites armored with glass fiber or other materials, with a unidirectional orientation, are used on a large scale at the production of structures, piece binding elements, electrical isolation tapes because they have good behavior to mechanical stresses and a high mechanical resistance to weight ratio. From the point of view of the advantages offered by these materials as: high toughness, relatively high temperature resistance, good mechanical resistance, high resistance to corrosion and wear, the question of why these materials are used on such a small scale in industry is raised. One of the problems they have is the one regarding their low machining property.

Therefore, in order to produce defect free holes and mechanical joining of composite structures, the process of drilling on GFRPs as well as nanopolymer composite laminates needs to be monitored.

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