Effects of Tool Geometry, Process Parameters and Fiber Orientation Angles on Hole Quality of (GFRP)

Ahmed M. Easa[1], Abeer S. Eisa[2]

[1]Professor, Production Engineering & Mech. Design Department, Faculty of Engineering, Menoufia University, Egypt

[2]Lecture, Production Engineering & Mech. Design Dept., Faculty of Engineering, Menoufia University, Egypt

Abstract: ***For fastening purpose, drilling is the most widely carried out manufacturing process for composites. Problems like surface delamination, inadequate hole surface finish are quite common in drilling hole. Therefore, the objective of the present research is to study the influence of five HSS twist drills with different point angles, five feed rates, three sets of fiber orientation angles and three of cutting speeds on the delamination and surface roughness of drilled hole. The analysis of the results demonstrated a strong association between the resultant of the delamination factor (df) with the feed rate and also with tool point angle when using all sets of fiber orientation angles (0/0/0/0),(0/45/45/0)and (0/90/90/0) with the three cutting speeds. The use of higher cutting speed (3000 rpm), fiber orientation angles (0/0/0/0) and low feed rate (25mm/min) with tool of point angle (60°) are suitable for drilling GFRP to get a good surface roughness of drilled hole.***

Keywords: Surface Quality, Surface Delamination, Drilling, Composite Materials, GFRP

1. Introduction

The effect of process parameters and tool geometry on the hole quality and the delamination are the key aspects that have been investigated in the last years. Cutting speed can lead to various effects on delamination, which depend on the specific range of variation considered and on the tool geometry used. The feed rate is found to have the biggest effect on the delamination and therefore a low value of feed rate is recommended. Also, the drilling performance may be effected by the type of workpiece material and tool material or coating. From the analysis of the results of this work, by using a standard twist drill, a low value of feed rate together with a high value of cutting speed can reduce the risk of delamination, Ruslan Melentiev, et al. [1]. Luís Miguel P., et al. [2] presented a comparative study on the different drill point geometries and feed rate for drilling of composite laminates. An experimental procedure is planned and consequences are evaluated. For this goal, monitoring during drilling the thrust force, hole wall roughness measurement and delamination extension assessment after drilling is accomplished. The laminates are drilled with the objective of comparing five different tool geometries, three feed rates and one cutting speed. The comparison results used for drill geometry are the maximum axial thrust force, hole surface roughness and delamination. The results of thrust force for a situation of one uncut ply are compared with known analytical models. From the analysis of the results, low feed rates may be appropriate for laminate drilling, as it reduces the axial thrust force and consequently, the risk of delamination onset, as is demonstrated by the analytical models. The preferred tool for higher feed rates is the special step drill and twist drill with a 120° point angle could also be a good option. The tool geometry had a large influenced on the results both for thrust force and delamination around the hole. The results indicated also that, a 120° twist drill should be used for minimal delamination and special step drill could present a good alternative, but the special step drill not commercially available yet.

The effect of tool geometry in drilling of CFRP composite through an experimental approach is studied by N. Vijay kumar, et al. [3]. The objective of this study is to compare and analyze the effect of tool geometry in drilling of CFRP composite through an experimental work. A standard tool and double cone drills are used in the drilling experiments of aerospace materials like CFRP. During drilling, thrust force, torque, tool wear and surface roughness are documented at regular intervals. Mathematical model for double cone tool geometry is developed for drilling CFRP and the empirical relation for torque and trust force is given. The double cone drill performs much better when compared to standard tool due to the reduced of trust force during drilling and tool life of double cone is longer than the standard tool .After drilling the required number of holes, the wear in double cone drill is small when compared with standard tool. In addition to, the surface roughness when used double cone tool is better than the standard tool. The thrust force and torque are increased with the increase of drill diameter and feed rate. This means that, for processing of continuously chip formation at high feed rates, high power requirement is demanded by tool to get rid of cutting and friction and extrusion forces. Therefore, they create high torque and thrust force in drilling operations. Vijayan Krishna raj, et al. [4] carried out a study on the effects of drill points on glass fiber reinforced plastic composite while drilling at high spindle speed. In this study, drilling experiments are conducted with standard point twist drill, Zhirov-point drill, and multi facet drill, using wide range of spindle speed, and feed rate to analyze thrust force, delamination and surface roughness. The analysis of this work indicated that, the surface roughness when used multi facet drill cuts is better than other drill geometries and also the delamination is less compared to the other drill geometries. The surface roughness when used multi facet drill is better at lower feed rate when compared to standard twist drill. The thrust force at the beginning of the cut increases sharply when used standard twist drill. From this analysis, high speed drilling, Zhirov point tool could be used to drill holes with lower thrust force and the life of the Zhirov point is also longer. E. Kilickap, et al. [5] try to investigate a correct selection of cutting parameters in order to reduce thrust force and may be reduce the delamination. The analysis of this work indicated that, a drill bit geometry reduces the indentation effect of the chisel-edge is preferable. The use of a pilot hole associated to twist drill tool has presented good results. It is may be due to the pilot hole cancels the chisel edge effect and reducing the risk of delamination. The analysis indicated that, the optimum drilling parameters combination was obtained by using the analysis of signal-to-noise ratio. Also, feed rate and cutting speed are the most influential factors on the delamination, respectively. The lower values of delamination were obtained at lower of cutting speeds and feed rates. Cutting parameters such as cutting speed, drill tool diameter and cutting fluids are optimized to obtain minimum surface roughness (Ra) using Taguchi method by Bhargab Kalita, et al. [6]. Drilling tests are performed on sensitive drilling machine using HSS drill bit on AISI B1113 mild steel plate. Experiments have been designed using Taguchi's L9 Orthogonal Array with three repetitions and the experiment is performed by varying all the parameters at three levels. The analysis indicated that, the optimum process parameters for minimum surface roughness are found to be cutting speed 1911 rpm, drill tool diameter 6mm and soluble oil as cutting fluid. Cutting speed is found to be the highest contributing factors with percentage contribution value 66.93% then drill tool diameter and cutting fluid. The minimum surface roughness range is also calculated and the predicted value of minimum surface roughness is obtained and confirmation experiment are 1.02 μm and 1.04 μm respectively. Dhiraj Kumar, et al. [7] presented an experimental investigation of delamination and surface roughness in the drilling of GFRP composite material with three dissimilar tools, having different materials and geometries (i.e. helical flute (HSS) drill, carbide tipped straight shank (K20) drill, and solid carbide eight-facet drill). The factors of delamination and adjusted delamination are calculated for the damage analysis of GFRP composite materials. Factor of adjusted delamination and surface roughness values are recorded for the helical flute HSS drill. The factors of delamination and adjusted delamination are lower for solid carbide eight-facet drill compared to the other two geometries at 1500 rpm and 0.02 mm/rev. Surface roughness values of the same tool are lower than that of the other two used drills. Solid carbide eight-facet drill is recommended for drilling of asymmetric laminate of GFRP composites. Also, carbide tipped straight shank (K20) drill can be used for drilling asymmetric laminates of GFRP composites, but its delamination factor, adjusted delamination factor and surface roughness values are more than the solid carbide eight-facet drills. Tsao, et al. [8], investigated the effects of drilling parameters on delamination by various step-core drills. From the analysis of this work, drilling-induced delamination of various step core drills is inversely related to diameter ratio and spindle speed and directly related to feed rate. H. Hocheng, et al. [9] introduced a relationship between spindle speed, feed rate and drill diameter to induced delamination in a CFRP laminate taking advantage of multiple regression analysis. The effect of spindle speed, feed rate, drill diameter and point angle on thrust force and torque during drilling of (BD CFRP) composite using two types of drilling high speed steel (HSS) and solid carbide drills is investigated. From the analysis, drill diameter, spindle speed and feed rate have statistical and physical significance on thrust force and torque, for both of the two used drills. The thrust force and torque values of in case of solid carbide drills are less compared to that in HSS drills. The minimum thrust force and torque are obtained at lower drill diameter, higher spindle speed, lower feed rate and minimum point angle both in HSS and solid carbide drills. The analysis of SEM images cleared that the damage caused by HSS drill is more severe compared to that caused by solid carbide drill. Therefore solid carbide drills could be the preferred choice for generating quality holes for structural applications. Gaitonde, et al. [10], developed a model based on response surface methodology for the study the effects of cutting speed, feed rate and point angle on delamination. The results of this work show that, a decrease in delamination tendency when cutting speed increases and also advise the use of low feed rates combined with adequate tool point angle. Palanikumar [11] conducted experiments on GFRP composites using Brad & Spur drill and optimized drilling parameters by using two input variables with four levels. The conclusion from the analysis of this work, low feed rate and high spindle speed are beneficial to reduce delamination.

D. Abdul Budan, et al. [12] studied the influence of fiber volume reinforcement in drilling GFRP laminates. The variation of tool wear, surface roughness, hole quality, chip characteristics, delamination factor with the variation of fiber volume reinforcement are studied. From the analysis of the results, it is obvious that, drilling of 70% fiber percentage content composites produced bad surface roughness. But the better surface finish is obtained for the composite with 30% fiber volume content and it is evident that the increase in fiber percentage is increased tool wear. Marilena Colt-Stoica, et al. [13] presented a paper on the defects in composite material caused by drilling in manufacturing Process. The holes are made and for each it is measured the drilling force and monitoring the surface quality and hole edge status. Also, some nondestructive methods of defect evaluation are presented. It is desired by knowing the loads and to optimize the process in terms of surface quality achieved because the cutting speed is still limited by the processing tool wear materials. While other damage modes such as matrix cracks may occur first, delamination result in larger stiffness drops and reduction in load-bearing capabilities. Delamination may occur from interlaminar stresses arising from geometric or material discontinuities from design features, such as an edge, a hole, a dropped ply. Local variations in volume fraction will always occur but large departures from specifications may be caused by inappropriate process conditions. Excess resin is important to avoid in pressurized or structural components such as pressure vessel. Rajesh Kumar Verma, et al. [14] presented a work on the machining of unidirectional glass fiber reinforced polymers (UD-GFRP) composites. For the manufacturer it is not easy to obtain quantitative and consistent measures but it has been mainly assessed by three parameters including tool wear or tool life, cutting forces or power consumption and better surface finish. It obvious that, good machinability means less tool wear, low cutting forces and good surface finish. Factors such cutting parameters, vibration, tool wear and fiber orientations should be taken very carefully during machining to obtain favorable environment for best quality as well as productivity. From the results of this work, conventional tools are not recommended for machining of composites, cutting tools such as cemented carbides, tungsten carbides, PCD, PCBN are widely used by the manufacturer. This approach can be recommended for continuous quality improvement of a process/product in any manufacturing/production environment. M. Henerichs, et al. [15] presented the analysis of fundamental tool-geometry based on orthogonal cutting of unidirectional CFRP-material. In this study, abrasive tool-wear, workpiece damages, and delamination are evaluated depending on different tool geometries and fiber-orientations. The experimental results in this work are based on the remaining five fiber orientations. Fiber orientations of ϴ = 30°, 60° and 90° appear to be the most critical orientations as they cause the highest process forces, the most intensive wear and workpiece damages. Feed rate can be reduced most efficiently with an increasing clearance angle. Cutting forces are influenced more dominantly by the clearance angle than by the rake angle. Tools with a small wedge angle and especially a large clearance angle are recommended to achieve lowest process forces. When using the fiber orientation of ϴ = 8°, the workpiece surface shows only few fiber breakages and a low roughness. Fiber orientations of ϴ = 30°, 60° and 90° show less spring-back and hence less wash out of matrix material with increasing clearance angle. Surface roughness increases for the fiber orientations of ϴ = 60° and 90° with increasing clearance angle. Also, surface roughness and subsurface damages appear most significant for a clearance angle α = 14°, tools with bigger clearance angles will be utilized in subsequent work. M. Sakthivel, et al. [16] presented a review on delamination in conventional and vibrated assisted drilling in glass fiber reinforced polymer composites. The main reason for delamination occurrence is due to performing of drilling in inefficient way. The various technique adopted for performing for assembling components drilling are conventional drilling, laser machining, water jet machining, wire cut electrical discharge machining, high speed drilling, vibration assisted drilling. The analysis of survey is proven that, vibration assisted drilling on composite materials possible to reduce delamination and increase tool life. This because the vibration assisted drilling intermittent contact between tool and work piece. Minimizing this vibration assisted drilling most suitable method compared to conventional drilling process. This vibration of tool or work piece minimized damages through VAD. Gheorghe Bejinaru Mihoc, et al. [17] presented a review on the drilling process of composite materials. In this work, a systematic analysis of the drilling process from the technological system, machine tool, tool, device and material processing is presented. This work is made to understand the mechanism generating the phenomenon of delamination. To obtain the desired quality performances at the composite material drilling, drill geometry and material have a major role and the resistance of the abrasive wear must be taken into consideration when choosing the drill tool material. The main problem of the defects met after the fabrication consists of the delamination of the hole.

From the deeply study of the previous literature review, it is clear that, there are a big variations between most of the previous results and also with the conclusions of these researches. Therefore, this field need more researches, and studies to understand and analyze the behavior of various defects specially delamination and surface roughness with different cutting parameters and different conditions of drilling accurately. The objective of the present research is to study the influence of three sets of fiber orientation angles [(0/0/0/0),(0/45/45/0) and (0/90/90/0)], three of cutting speeds (1000, 2000 and 3000 rpm) ,five HSS twist drills(same diameter φ 8mm –five different point angles,60,70,80,90 and 100°),and five feed rates (25, 50 , 75,100 and125 mm/min) on delamination and surface roughness of drilled hole.

2. Experimental Work

2.1 Materials and Process Parameters

In this work, glass fiber is used as reinforcement in the form of bidirectional fabric (Standard E-Glass Fiber glass) and polyester with catalyst addition as matrix for the composite material. The material used is a typical composite plate of dimensions (200×40×20 mm) with fiber volume fraction ratio 60%. The specimen is constituted by four layers with different fiber orientation angles as follows; Set (1): [/0/0/0/0], Set (2): [0/45/45/0] and Set (3): [0/90/90/0].
During the manufactured of specimens, the orientation of the fibers on the work piece has been set. The plates are fabricated by hand lay-up process followed by a cure process under constant pressure. The mechanical properties of the used composite are calculated analytically using the mixture rules. The material properties are shown in Table (1).

2.2. Tools and parameters

Five different point angles twist drills made of high-speed steel (HSS), φ 8 mm are used for the drilling operations. The tips of the drills are ground to have drill point angles of (60, 70, 80, 90 and 100°) .To prevent the effect of twist drill wear on the experiments results, each of them is used for making five holes only. The cutting parameters and their levels are listed in Table (2).

3. Experimental Setup

3.1. Drilling operation setup

The Machine which used to perform the experiments is an Extron M218, LH, CNC Machine. The feed rate and spindle speed are controlled by a programs which written specifically for drilling of composites. Three of cutting speeds and five feed rates can be used to obtain different surface roughness.

Table 1: Material properties due to (International System – SI)

Material	Properties	Symbol	Value	units
Glass Fiber	Elasticity Modulus Density Poisson´s coefficient	Ef ρf υf	76.00x109 2.56x103 0.22	[N/m2] [Kg/m3]
Poly-ester	Elasticity Modulus Density Poisson´s coefficient	Em ρm υ m	4.00x109 1.30x103 0.40	[N/m2] [Kg/m3]
Composite material	Elasticity Modulus of Fiber direction Normal to fiber Density Shear Modulus Poisson´s coefficient Fiber volume fraction	E11 E22 ρc G12 υ 12 Vf	44.8x109 11.27x109 1780 4.86x109 0.28 60%	[N/m2] [N/m2] [Kg/m3] [N/m2]

Table 2: Used Parameter and Their Levels.

Parameters	Unit	1	2	3	4	5
Cutting speed	rpm	1000		2000		3000
Feed rate	mm/min	25	50	75	100	125
Volume fraction ratio	%	60				
Fiber orientation angles	0/0/0/0	0/45/45/0		0/90/90/0		
Used Tools	Five different point angles Twist Drills, (φ 8 mm)					

3.2. Surface roughness measurements

The machined holes are prepared for measurements. The measurements of surface roughness are performed using SJ-201P surface test. The measurements are made after the calibration of the instrument and with the cut-off length of (0.8mm) according to (ISO 4287-1997). Surface roughness of the hole is measured at entry, middle and exit of the drilled hole and the average value of surface roughness is considered for the investigation.

4. Results and Discussion

The analysis of the experimental results has been carried out to study the influence of the following input process parameters; three sets of fiber orientation angles and three of cutting speeds (rpm), five of feed rates (mm/min) and five of tools (HSS - different point angles) on the process responses, i.e. delamination (df) and surface roughness (Ra) of the drilled hole (when using volume fraction ratio 60 %). From the deeply study of the previous literature review, it is recommended that, the proposed methodology of experiments is suitable for analysis the surface roughness at drilling of GFRP.

4.1. Delamination Assessment

For study and analyze the influence of drilling process conditions which mentioned before in machining of GFRP composites, the surface roughness values of drilled holes are measured and the delamination is measured and calculated[18]. The results of both are plotted as shown in Figures (2-19).

In Figure (2), fiber orientation angles (0/0/0/0) and three parameters are used; cutting speed (1000rpm), five feed rates [25, 50, 75,100 and125 mm/min-(f)] and five tools of different point angles (60, 70, 80, 90 and 100°). From this figure, the delamination factor (*df*) is increased with the increase of feed rate and also with the increase of tool point angle. The delamination factor is increased from 1.055 to 1.073, 1.082, and 1.09 and to 1.102 for feed rates 25, 50, 75,100 and 125 mm/ min and with tool of point angle (60°). Also, with feed rate 25 mm/min, it is increased with the increase of tool point angle from 1.055 with tool of point angle (60°) to 1.073,1.082,1.09 and 1.102 for the others tools(70, 80, 90 and 100°) respectively. The percentage of increase is 2.18% between the small and big point angle tools (60 and 100°) when feed rate was 25 mm/min. In the other side, the increase in (*df*) is 2.18% between feed rate 25 and 125 mm/min for the tool of point angle (60°). The analysis indicated that, the increase in the point angle of used tool is led to an increase in the values of (*df*) in the produced hole, but low values of (*df*) are shown with tool of small point angle. Also, it is obvious that, the low values of (*df*) are shown with the low feed rate values. The increase of point angle of used tool led also to obvious increase in delamination factor (*df*). The increase of (*df*) with the increase of tool point angle may be due to the increase of friction effect produced by drill tool at entry of the hole due to the increase of point angle. These results asserted that, the feed rate is the main parameter which effect on the delamination factor during drilling. Also, (*df*) is increased with the increase of tool point angle when using fiber orientation angles (0/0/0/0) and cutting speed 1000rpm. In Figure (3), fiber orientation angles is changed to (0/45/45/0) and the other three parameters as maintained in the previous figure. From this figure, the delamination factor (*df*) is increased with the increase of both; feed rate and tool point angle. But the values of (*df*) is bigger than that when used fiber orientation angles (0/0/0/0) with the same parameters. It evident that, when used fiber orientation angles (0/45/45/0) a bad surface at entry of the drilled hole is produced and this led to bigger values of (*df*) as compared with the previous fiber orientation angles (0/0/0/0) with the same cutting speed. From In Figure (4), it can be seen that, fiber orientation angles is the main parameter which effect on the delamination factor during drilling when using mentioned parameters.

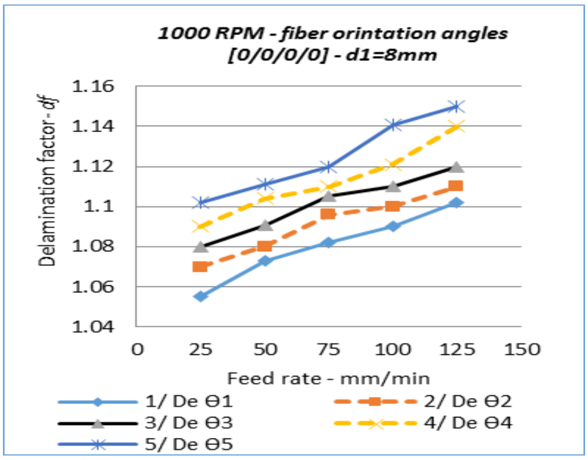

Figure 2: (*df* - *f*) Relation at; five tools of different point angles, Fiber orientation angles [0/0/0/0] and RPM 1000.

The increase of point angle of used tool is led to obvious increase in (*df*) in the produced hole. The delamination factor (*df*) is increased from 1.09 to 1.105, 1.11, and 1.123 and to 1.14 for feed rates 25, 50, 75,100 and 125 mm/ min respectively. Also, with feed rate 25 mm/min, (df) is increased with the increase of tool point angle from 1.09 with tool of point angle (60°) to 1.1 ,1.11 ,1.12 and 1.133 for the others tools(70, 80, 90 and 100°).The percentages of increase due to change fiber orientation angles to (0/45/45/0) with the tool of (70°) and with the used feed rates are; 1.38,1.49,1.17,1.48 and 1.77% and for tool of point angle (80°) are; 1.37, 1.31, 0.9, 1.33and 1.77 for the used feed rates. For the tool of point angle (90°) and with the used feed rates the percentages of increase are; 1.36, 1.16, 1.78, 1.62 and 1.17%, and when used tool of point angle (100°) the percentages of increase are; 1.39, 1.42, 1.75, 1.25 and 1.29%. It is clear that, the increase of point angle of used tools is led to obvious increase in (*df*) values as analyzed in the previous part. Also, the change of fiber orientation angles from (0/0/0/0) to (0/45/45/0) is led to an increase in all values of delamination factor (*df*) with the different feed rates and also with the different used tools.

The results in the previous figure demonstrated a very strong association between the resultant of delamination factor (*df*) with fiber orientation angles, feed rate and tool point angle when used cutting speed 1000rpm.

The plotted results in Fig. (4) are due to the change of fiber orientation angles from (0/45/45/0) to (0/90/90/0) and the other parameters are still as shown in Figs.(2 and 3). From this figure, the values of (*df*) are increased with the increase of feed rate and also with the increase of tool point angle, but the values of (*df*) are less than that when used fiber orientation angles (0/45/45/0) with the same parameters.

The percentages of the decrease due to change of fiber orientation angles with different feed rates are; 0.93, 0.96, 0.91, 0.94 and 1.2% for tool of point angle (60°). When used tool of point angle (70°) the decreases are; 0.92, 1.04, 0.99, 1.02 and 0.88% for the used feed rates respectively. For tool of point angle (80°) the decreases are; 0.91, 0.90, 0.89, 0.44 and 0.74%.

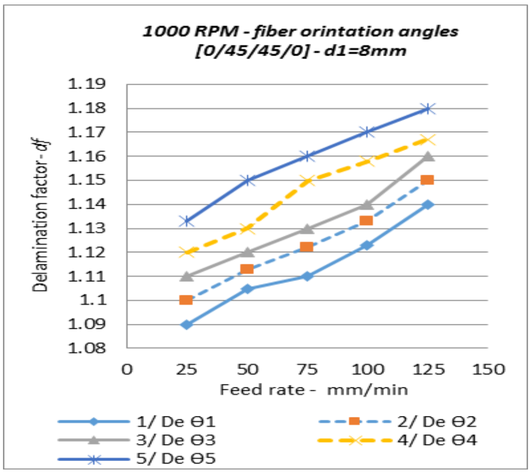

Figure 3: (*df* - *f*) Relation at; five tools of different point angles, Fiber orientation angles [0/45/45/0] and RPM 1000.

With the tools of point angles (90°and 100°), there are different values of (*df*), these values is led to another percentages of decrease as follow; 0.90, 0.89, 0.88, 0.61and 0.56% for (90°) and for (100°) are; 0.1, 0.88, 0.87, 0.43 and 0.43% with the used feed rates. From these results, it is obvious that, the fiber orientation angles play a vital role in the resultant of delamination factor (*df*). Also, feed rate and tool point angle are had a large effect on the resultant values of (*df*) with the same cutting speed.

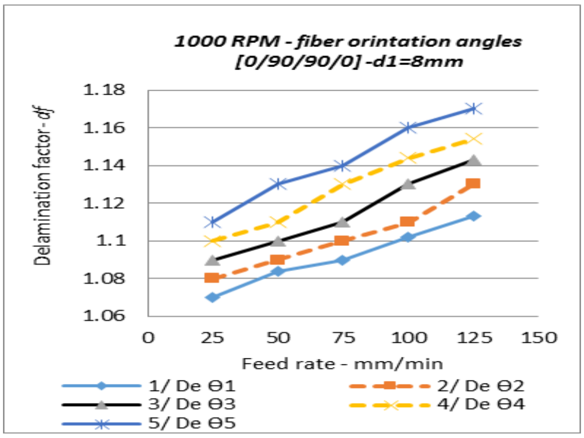

Figure 4: (*df* - *f*) Relation at; five tools of different point angles, Fiber orientation angles [0/90/90/0] and RPM 1000.

From Figures (2, 3 and 4), it is clear that, the delamination factor (*df*) is increased with the increase of feed rate and also with the increase of tool point angle. The average increase in (*df*) due to the increase in feed rate between 5 and 125 mm/min is; 2.04% with fiber (0/0/0/0), 2.15% with (0/45/45/0) and 1.51% with (0/90/90/0) for the different tools.

Figure (5) shows the relation between (*df*) and five of feed rates (*f*) with fiber orientation angles (0/0/0/0) and five used tools when the cutting speed is changed to (2000rpm).From this figure, the delamination factor(*df*) is increased with the increase of feed rate and also with the increase of tool point angle. For tool of point angle (60°), (*df*) is increased from 1.07 to 1.077, 1.09, and 1.105and to 1.11 for feed rates 25, 50, 75,100 and 125 mm/ min respectively. Also, with feed rate 25 mm/min, (*df*)is increased with the increase of tool point angle from 1.07 with tool of point angle (60°) to 1.08,1.09,1.102 and 1.12 for the others tools(70, 80, 90 and 100°).

The percentages of the increase is 3.2% between the small point angle tool (60°) and big one (100°) when feed rate is 125 mm/min .The analysis indicated that, the increase in the point angle of tool is led to an increase in the delamination factor (df) in the produced hole and low value of (df) is shown with tool of small point angle.

The comparison between the two cutting speeds 1000 and 2000 rpm when used fiber orientation angles (0/0/0/0) is demonstrated that, the increase of cutting speed led to an increase of the delamination factor (df).The average of the increase in (*df*) with the used feed rates and tool of point angle(60°)is 0.43%. But the (*df*) average is increased between the small and the big point angle tool to 0.46% for the different feed rates. From the results shown in Figures (2 and 5), it is clear that, the cutting speed have a large effect on the resultant delamination factor (*df*) and is led to an increase in the resulted values as shown.

The analysis of results demonstrated a very strong association between the resultant of delamination factor (*df*) with cutting speed, feed rate and the values of point angle of the used tool respectively.

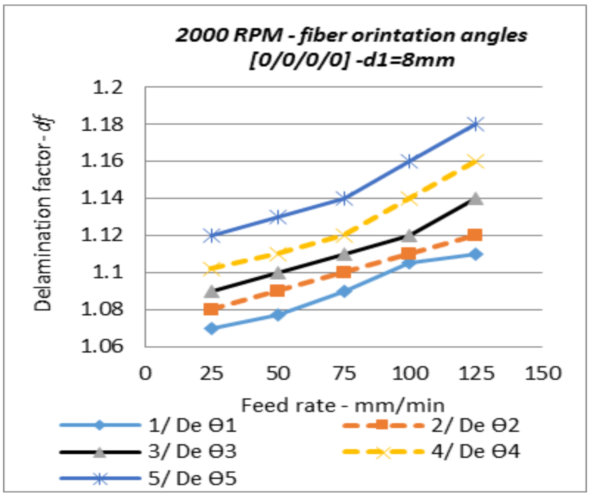

Figure 5: (*df* - *f*) Relation at; Five tools of different point angles, Fiber orientation angles [0/0/0/0] and RPM 2000.

In Figure (6) the fiber orientation angles is changed from (0/0/0/0) to (0/45/45/0) with the same cutting conditions used in Fig. (5). The delamination factor (*df*) is increased with the increase of both; feed rate and tool point angle. For the tool of point angle (60°), (*df*) is increased from 1.1 to 1.114, 1.12, and 1.132 and to 1.136 µm for feed rates 25, 50, 75,100 and 125 mm/ min respectively. With feed rate 25 mm/min, (*df*) is increased with the increase of tool point angle from 1.1 with angle (60°) to 1.11, 1.121, 1.131 and 1.14 for the others tools (70, 80, 90 and 100°). The comparison between the two fiber orientations is demonstrated that, the change of fiber orientation from (0/0/0/0) to (0/45/45/0) led to an increase in (*df*) with the same cutting speed 2000rpm. The increase due to change of fiber orientation and for different used tools and with feed rate 25 mm/min are; 1.38, 1.36, 1.4, 1.24 and 0.88%. But with the biggest feed rate, these values are changed to; 1.16, 1.1, 0.70, 0.43and 0.42% for the five drilling tools and with the cutting speed 2000 rpm.

From the analysis of these results, it is obvious that, the fiber orientation plays a vital role in the resultant delamination factor (*df*). Also, tool point angle and feed rate are had a large effect on the resultant delamination factor (*df*) when used cutting speed 2000 rpm.

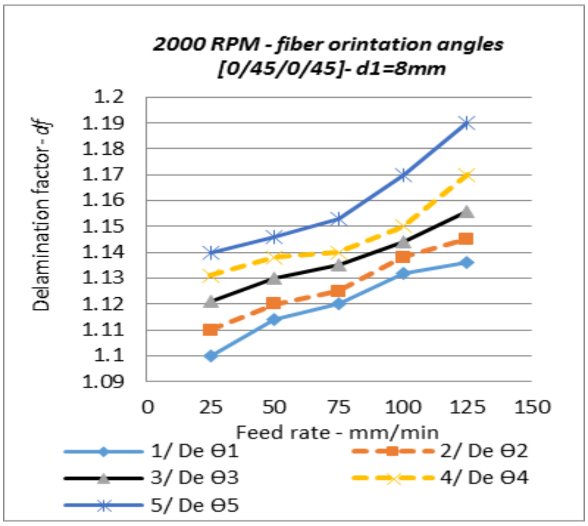

Figure 6: (*df* - *f*) Relation at; five tools of different point angles, Fiber orientation angles [0/45/45/0] and RPM 2000.

In Figure (7), the plotted results are due to the change of fiber orientation angles from (0/45/45/0) to (0/90/90/0) and the other parameters are still as shown in Fig. (6). Delamination factor (*df*) is increased with the increase of feed rate and also with the increase of tool point angle. The comparison between the results of the two fiber orientations is demonstrated that, the change of fiber orientation from (0/45/45/0) to (0/90/90/0) is led to a decrease in values of (*df*) with the same cutting speed 2000rpm. The decrease in (*df*) due to change of fiber orientation and for different used tools with feed rate 25 mm/min are; 1.38, 0.91, 0.94, 0.94 and 0.44% respectively. But when used the biggest feed rate, the values of (*df*) are changed to; 0.26, 0.22 0.0.26, 0.21and 0.17% for the five drilling tools and with cutting speed 2000 rpm.

From this figure, it can be asserted that, fiber orientation is the main parameter which effect on the delamination factor during drilling with the mentioned parameters. The increase of point angle of used tool is led also to obvious increase in delamination factor (*df*). From the analysis of the results which are plotted in Fig.(7),feed rate and tool point angle are had an obvious effect on the resultant delamination factor (*df*) when used cutting speed 2000 rpm and fiber orientations (0/90/90/0).

From Figures (5, 6 and 7), it is clear that, the delamination factor (*df*) is increased with the increase of feed rate and also with the increase of tool point angle. The average of increases are as follow when used rpm 2000, between feed rate 25 and 125 mm/min and for the used tools; 2.22% with (0/0/0/0), 1.71% with (0/45/45/0) and 2.31% with (0/90/90/0).

Also, from the same figures, the change of fiber orientation angles plays a vital role in the resultant (*df*). The change in average percentages due to change of fiber orientation angles are as follow when used rpm 2000 and feed rate 25mm/min; 0.75% with (0/0/0/0) to (0/45/45/0) and decreases to 0.62% from (0/45/45/0) to (0/90/90/0).

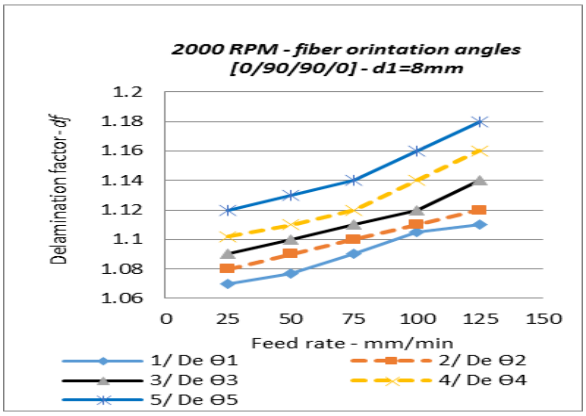

Figure 7: (*df* - *f*) Relation at; five tools of different point angles, Fiber orientation angles [0/90/90/0] and RPM 2000.

The results in Fig.(8) are plotted due to the following parameters; five drilling tools with five different point angles, five feed rates ,fiber orientation angles (0/0/0/0) and cutting speed is increased to 3000 rpm. From this figure, the delamination factor (*df*) is increased with the increase of both feed rate and tool point angle. Delamination factor (*df*) is increased from; 1.08 to 1.085, 1.1, and 1.115 and to 1.12 for feed rates 25, 50, 75,100 and 125 mm/ min respectively. Also, with feed rate 25 mm/min, (*df*) value is increased with the increase of tool point angles from; 1.08 with tool of point angle (60°) to 1.091, 1.101, 1.111 and 1.121 for the others tools (70, 80, 90 and 100°). The percentage of increase is 1.99% when change feed rate from 25 to 125 mm/min between the small and big point angle tools (60 and 100°).
The analysis indicated that, the increase in the point angle of tool led to an increase in the values of delamination factor (*df*) in the produced hole, but low values of (*df*) are shown with tool of small point angle. Also, the low values of (*df*) are shown with the low values of feed rates.

From these results, it can be asserted that, feed rate is the main parameter which effect on the delamination factor during drilling operation. The increase of point angle of used tool is led to obvious increase in delamination factor (*df*). These results demonstrated an association between the delamination factor values (*df*) with feed rate and tool point angle when using fiber orientation angles (0/0/0/0) and cutting speed 3000rpm.

In Figure (9), the same parameters which are used in the previous figure, but the fiber orientation is changed to (0/45/45/0). Delamination factor (*df*) is increased with the increase of feed rate and also with the increase of tool point angle. In this case, the values of (*df*) is bigger than that when used fiber orientation (0/0/0/0) with the same parameters. It is evident that, when used fiber orientation angles (0/45/45/0) a bad surface is shown at entry of the drilled hole and this lead to big values of (*df*) as compared with the previous fiber orientation angles (0/0/0/0) with the same cutting speed 3000 rpm. From this figure, it can be seen that, fiber orientation angles is the main parameter which effect on the delamination factor during drilling when using the fiber orientations angles (0/0/0/0) and cutting speed (3000rpm).

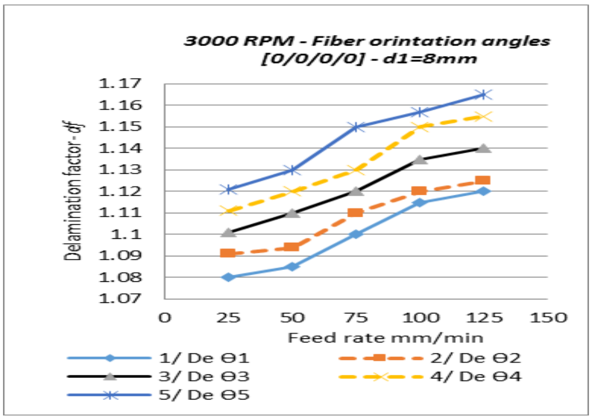

Figure 8: (*df* - *f*) Relation at; five tools of different point angles, Fiber orientation angles [0/0/0/0] and RPM 3000.

The increase of point angle of used tool is led to obvious increase in (*df*) of the produced hole. The delamination factor (*df*) is increased from 1.11 to 1.12, 1.13, and 1.138 and to 1.145 µm for feed rates 25, 50, 75,100 and 125 mm/ min, with tool of point angle (60°). Also, with feed rate 25 mm/min, it is increased with the increase of tool point angle from 1.12 with tool of point angle (70°) to 1.13 ,1.138 and 1.145 for the others tools (70 ,80, 90 and 100°).In the other hand, the percentages of increase due to change of fiber orientation and point angle of different used tools and for feed rate 25 mm/min are;0.14,0.13,0.13,0.12 and 0.11.When used tool of point angle (70°), the percentages of increase with the used feed rates are; 0.13, 0.18, 0.12, 0.11 and 0.11 % respectively. The increase for the other three tools are; 0.9, 0.8, and 0.8%. The results demonstrated a strong association between the resultant values of (*df*) with fiber orientation angles, feed rate and tool point angle when used fiber orientation angles (0/45/45/0) and cutting speed 3000rpm.

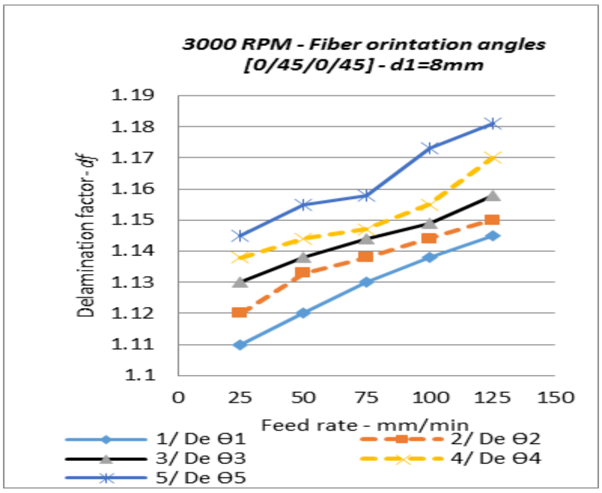

Figure 9: (*df* - *f*) Relation at; Five tools of different point angles, Fiber orientation angles [0/45/45/0] and RPM 3000.

The used parameters in Fig. (10) are; fiber orientation angles (0/90/90/0) and the other parameters are still as shown in Fig. (9). Delamination factor (*df*) is increased with the increase of feed rate and also with the increase of tool point angle. The comparison between the results of the two fiber orientations is demonstrated that, the change of fiber orientations from (0/45/45/0) to (0/90/90/0) is led to a decrease of (*df*) with the same cutting speed 3000rpm. The decrease due to change of fiber orientation and for different used tools with feed rate 25 mm/min are; 0.91, 0.91, 0.44, 0.35 and 0.22% respectively. With the tool of point angle (70°) these values are; 0.45, 0.10, 0.35, 0.18and 0.26%. When used the biggest feed rate with the tool of biggest point angle, the values of (*df*) are changed to 0.22 for feed rate 25 mm/min to 0.47 % for feed rate 125mm/min.

From the analysis of the results, it can be asserted that, fiber orientation angles, cutting speed and feed rate with tool point angle are the main parameters which effect on the delamination factor (*df*) during drilling.

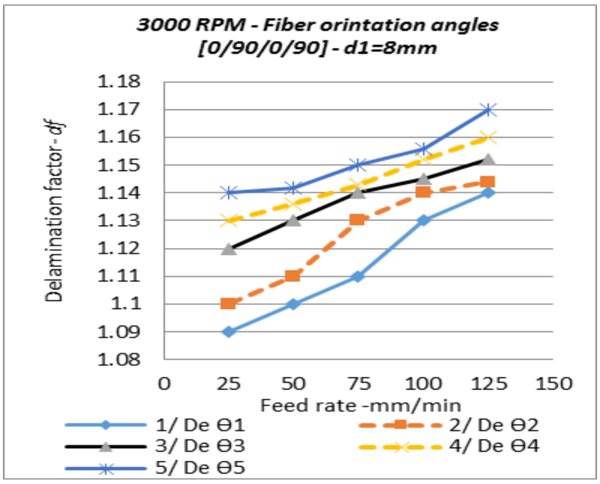

Figure 10: (*df* - *f*) Relation at; Five tools of different point angles, Fiber orientation angles [0/90/90/0] and RPM 3000.

From the previous figures (8, 9 and 10), it is clear that, the delamination factor (df) is increased with the increase of feed rate and also with the increase of tool point angle. The average percentages of increase are as follow when used rpm 3000, feed rate between 5 and 125 mm/min and for the different used tools; 1.79 % with (0/0/0/0), 1.41% with (0/45/45/0) and 1.64 with fiber orientation angles (0/90/90/0). Also, the change of fiber orientation angles plays a vital role in the resultant (*df*). The change in average percentages due to change of fiber orientations are as follow when used RPM 3000 with different tools and feed rate 25 mm/min; 0.14% from (0/0/0/0) to (0/45/45/0), 0.24% decreases from (0/45/45/0) to (0/90/90/0).

Also, from the previous figures (2-10) and with the deeply analysis, it obvious that, the big values of (*df*) are shown with fiber orientation angles (0/45/454/0) when used with the three cutting speeds. The increase in the values of (*df*) with the set of (0/45/45/0) may be due to increase in the broken fibers during drilling operation. Fiber orientations of (0/45/45/0) appear to be the most critical orientations as they causes the biggest delamination factor (*df*) and workpiece damages.

The analysis reveals that, there is a positive correlation between the increase of feed rates and the increase in delamination factor. The increase of feed rate to 100 and 125 mm/min is led to an increase of the broken fibers quantities. It is led to an increase of the friction between the tool and the wall of hole and produce a bad surface at the hole entrance and respectively increased the delamination factor (*df*). Tearing delamination is observed during used drills of big point angles and poor machining quality is obtained. When using big point angles drills, the increased of (*df*) is due aggressive drilling process and serious tearing delamination is found especially when feed rate is 100 mm/min and more for all fiber orientations used [19].

4.2. Surface roughness Assessment

In the following part, the surface roughness results of drilled hole will be analyzed and discussed. As mentioned before, the surface roughness of the drilled hole is measured at entry, middle and exit and the average value of surface roughness is considered for this investigation. Thus, the plotted value of (*Ra*) is due to the average value of the surface roughness of the drilled hole.

In Figure (11), the three used parameters are; cutting speed (1000rpm), five feed rates [25, 50, 75,100 and125 mm/min-(f)] and five tools of different point angles (60, 70, 80, 90 and 100°) with fiber orientation angles (0/0/0/0). From the results, with feed rate (f) 25mm/min, (*Ra*) is increased from; 6.0 to 7.6, 9.0, 10.6 and 12 µm with the increase of tool point angles. The values of increase in (*Ra*) with the increase of used feed rates (f) are; 6.0 to 7.2, 8.1, 10.7 and 12.2 µm. The percentage of increase in (Ra) between the small and big point angle tools (60 and 100°) is 0.33% with feed rate (*f*) 25 mm/min. In the other side, the percentage of increase in (*Ra*) between the small and big point angle tools (60 and 100°) is 0.35 with feed rate 125 mm/min. The analysis indicated that, the increase in point angle of used tool led to an increase in surface roughness (*Ra*) in the produced hole, but the low value of (Ra) is shown with tool of small point angle. The increase of surface roughness (*Ra*) with the increase of tool point angle may be due to the increase of friction effect produced by drilled tool at the wall of the hole due to the increase of point angle. These results demonstrated a strong association between the resultant of surface roughness (*Ra*) with feed rate (f) and tool point angle when using fiber orientation angles (0/0/0/0) and cutting speed 1000rpm.

In Figure (12), fiber orientation angles is changed to (0/45/45/0) and other three parameters are the same which used in the previous figure. The surface roughness (*Ra*) is increased with the increase of both; feed rate and tool point angle. But the values of surface roughness (*Ra*) is bigger than that when used fiber orientation angle (0/0/0/0) with the same other parameters. From the results shown in Fig. (12), fiber orientation angles is the main parameter which effect on the surface roughness (*Ra*) during drilling. The analysis of the results indicated that, the increase of point angle of used tool led to obvious increase in surface roughness (*Ra*) in the produced hole. The value of surface roughness (*Ra*) is increased from; 9.0 to 11, 13, 17 and 20 µm with the five used tools and feed rate 25mm/min.

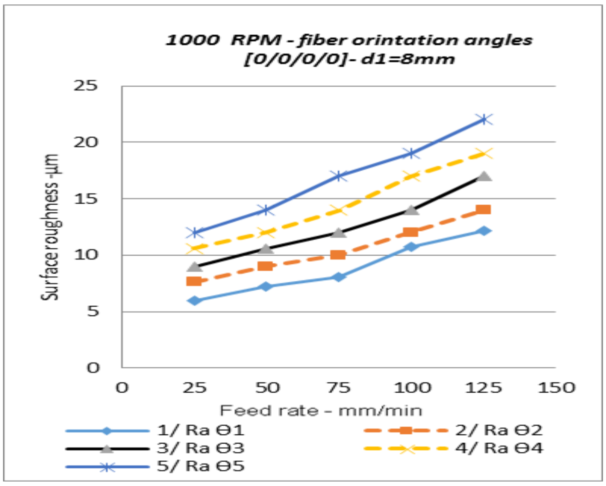

Figure 11: (Ra - *f*) Relation; Five tools of different point angles, Fiber orientation angles [0/0/0/0] and RPM 1000.

The increase due to change of fiber orientation with small point angle (60°) and with different used feed rates are; 9.0, 11.2, 13.1, 15 and 16 µm. The percentages of increase due to change of fiber orientation from (0/0/0/0) to (0/45/45/0) with the tool of (70°) and with the used feed rates are; 18.28, 18.18, 20, 22.6 and 20%.In the other side, the increase due to change of fiber orientation with the different feed rates and tool of point angle (100°) are; 25, 22.2, 32, 19.05, 17.39 and 12%. The analysis of these results indicated that, the fiber orientation angles, feed rates and point angle of the tools are play a vital role in the resultant of surface roughness (*Ra*) with cutting speed 1000 rpm.

The plotted results in Fig. (13) are due to the change of fiber orientation angles from (0/45/45/0) to (0/90/90/0) and other three parameters are the same which used in the previous figure. Surface roughness (*Ra*) is increased with the increase of feed rate and also with the increase of tool point angle. The values of (*Ra*) are less than that when used fiber orientation angles (0/45/45/0) and with the same parameters. The percentages of decrease due to change of fiber orientation angles with different feed rates and tool of point angle (60°) are; 12.5, 10.9, 8.71, 11.11 and 8.47%. But with the increase of tool point angle, the values of surface roughness (*Ra*) are changed to;10,8.33,7.14,11.76 and 13.51for tool (70°) and11.11,12.82,16.28,12.5 and 12% for the tool of point angle (100°).

From these results, it is obvious that, the fiber orientations play a vital role in the resultant surface roughness (*Ra*). Also, tool point angle and feed rate are had a large effect on the resultant surface roughness (*Ra*) when used cutting speed 1000rpm.

The analysis of the previous results in Figs.(11 ,12 and 13) demonstrated a strong association between the results of surface roughness (Ra) with the feed rate , tool point angle and cutting speed when using all sets of fiber orientation angles (0/0/0/0),(0/45/45/0)and (0/90/90/0).

When used rpm1000, the change in the average percentages due to change in feed rate from 25 to 125 mm/min and with different fiber orientation angles are as follow; 30.1% with (0/0/0/0), 31% with (0/45/45/0) and 28.33% with (0/90/90/0) for the different used tools.

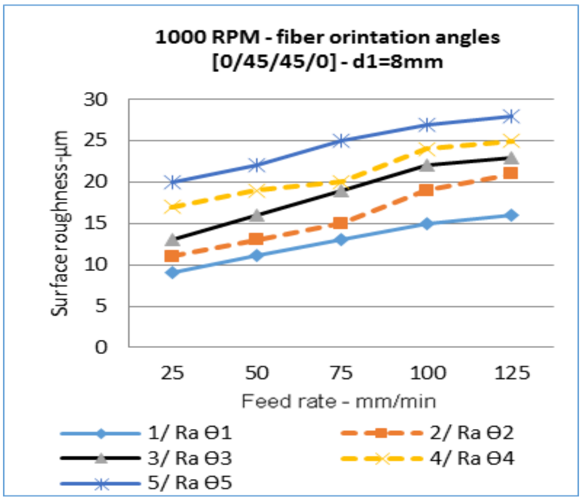

Figure 12: (Ra - *f*) Relation; Five tools of different point angles, Fiber orientation angles [0/45/45/0] and RPM 1000.

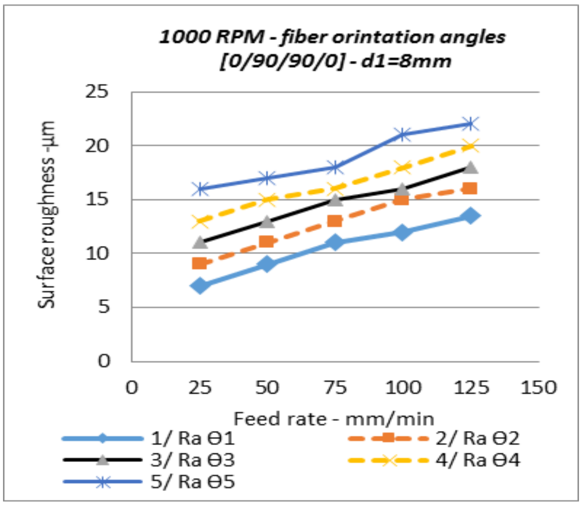

Figure 13: (Ra - f) Relation; Five tools of different point angles, Fiber orientation angles [0/90/90/0] and RPM 1000.

In Figure (14), the fiber orientation angles is changed to (0/0/0/0) and the cutting speed is changed also to (2000rpm) and other two parameters are the same which used in the previous figure. From Figure (14), (*Ra*) is increased with the increase of both, feed rate and tool point angle. For the tool of point angle (60°), the value of (*Ra*) is increased from 4.2 to 6.1, 7.3, and 8.0 and to 10.6 µm for feed rates 25, 50, 75,100 and 125 mm/ min respectively. Also, with feed rate 25 mm/min, the value of (*Ra*) is increased with the increase of tool point angle from 4.2 with tool of point angle (60°) to 6.2,8.1,9.0 and 10.8µm for the others tools(70, 80, 90 and 100°). The average percentage of increase is 43.2% for the tool of small point angle (60°) and 0.25.52% for big one (100°) when change feed rate from 25 to125 mm/min. The analysis indicated that, the increase in the point angle of tool led to an increase in (*Ra*) values. Low value of (*Ra*) is shown with tool of small point angle. The comparison between the two cutting speeds 1000 and 2000 rpm when used fiber orientation angles (0/0/0/0) is demonstrated that, the increase of cutting speed led to a decrease of the surface roughness

(*Ra*). It is evident that, the cutting speed play a vital role on the resultant values of the surface roughness (*Ra*).

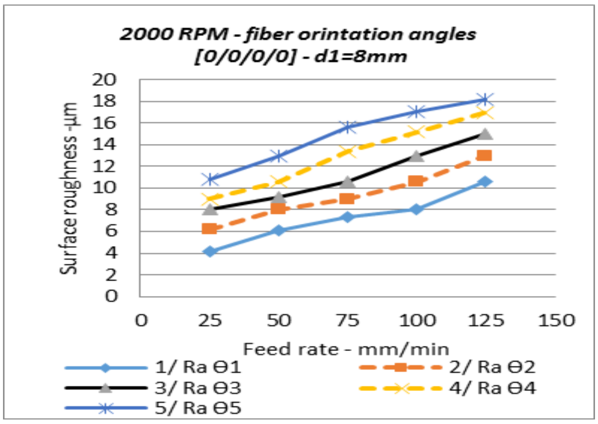

Figure 14: (Ra - f) Relation; Five tools of different point angles, Fiber orientation angles [0/0/0/0] and RPM 2000.

The relation between (*Ra - f*) at ; five drilling tools with five different point angles, fiber orientation angles (0/45/45/0) and cutting speed 2000 rpm is shown in Fig. (15). The results in this figure indicated that, the surface roughness (*Ra*) is increased with the increase of both, feed rate and tool point angle. For tool of point angle (60°), (*Ra*) is increased from; 5.2 to 7.0, 9.1, 10.0 and 12.5µm for feed rates 25, 50, 75,100 and 125 mm/ min respectively. With feed rate 25 mm/min, (*Ra*) is increased with the increase of tool point angle from 5.2 with tool of point angle (60°) to 7.2, 9.0, 13 and 16 µm and for the others tools (70, 80, 90 and 100°).

The comparison between the two fiber orientations is demonstrated that, the change of fiber orientation from (0/0/0/0) to (0/45/45/0) led to an increase of the surface roughness (*Ra*) with the same cutting speed 2000rpm. The increase due to change of fiber orientations and for different used tools and with feed rate 25 mm/min are; 10.6, 7.46, 6.43, 18.18 and 19.4%, but with the biggest feed rate, these values are changed to; 8.23, 7.47, 6.25, 8.12and 11.65% for the five drilling tools with the same cutting speed. From the analysis of these results, it is obvious that, the fiber orientation plays a vital role in the resultant values of surface roughness (*Ra*). Also, tool point angle and feed rate are had a large effect on the resultant surface roughness (*Ra*) when used cutting speed 2000 rpm.

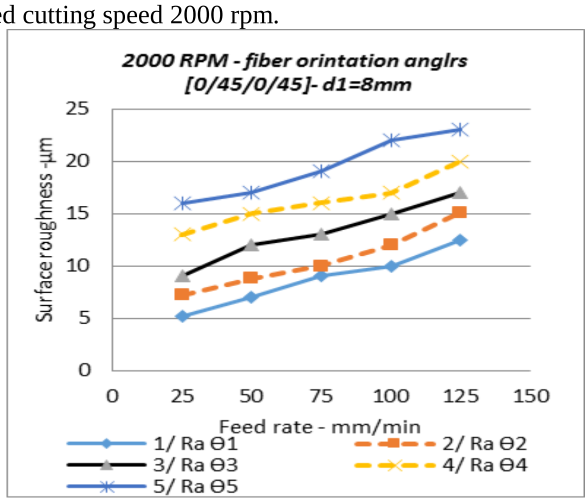

Figure 15: (Ra - f) Relation; Five tools of different point angles, Fiber orientation angles [0/45/45/0] and RPM 2000.

In Figure (16), the plotted results are due to the change fiber orientation angles from (0/45/45/0) to (0/90/90/0) and other three parameters are the same which used in the previous figure. (*Ra*) is increased with the increase of both; feed rate and tool point angle. The comparison between the results of the two fiber orientations is demonstrated that, the change of fiber orientation from (0/45/45/0) to (0/90/90/0) led to a decrease in the values of (*Ra*) with the same cutting speed 2000rpm. The percentages of decrease due to the change of fiber orientation and for different used tools with feed rate 25 mm/min are; 13.04, 9.09, 5.9, 8.33 and 10.34%, but when used the biggest feed rate, the percentages of decrease are changed to; 6.38, 3.78, 3.03, 2.56 and 4.55%. In the other side, the values of decrease in (*Ra*) values when used different feed rates with small and big tools are;13.04 ,16.7 ,20.53,5.26 and 6.38 % and 10.34 , 6.25 , 5.56 ,7.32 and 4.55 % respectively. From Figure (16), it can be asserted that, fiber orientation is the main parameter which effect on the surface roughness (*Ra*) during drilling with the mentioned parameters. The increase of point angle of the used tool is led to obvious increase in surface roughness (*Ra*). Tool point angle and feed rate are had also an obvious effect on the resultant surface roughness (*Ra*) when used cutting speed 2000 rpm and fiber orientation angles (0/90/90/0) .

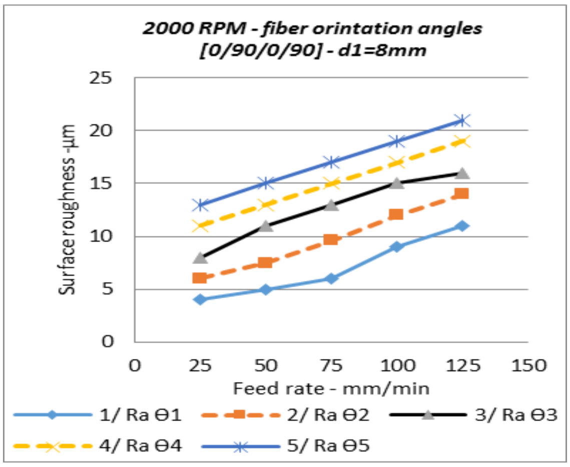

Figure 16: (Ra - f) Relation; Five tools of different point angles, Fiber orientation angles [0/90/90/0] and RPM 2000.

From the previous figures (14, 15 and 16), it can be seen that, when used rpm 2000, the change in average percentages due to change in feed rate between 25 and 125mm/min with different fiber orientation angles are as follow; 34.71% with (0/0/0/0), 37.78% with (0/45/45/0) and 41.67% with (0/90/90/0).

In Figure (17), the results are plotted due to the following parameters; five drilling tools with five different point angles, fiber orientation angles (0/0/0/0) and cutting speed 3000 rpm. From this figure, the surface roughness (*Ra*) is increased with the increase of both, feed rate and tool point angle. (*Ra*) is increased from 2.5 to 4.1, 6.0, and 8.2 and to 9.1µm for feed rates 25, 50, 75,100 and 125 mm/ min and tool of point angle (60°).

Also, with feed rate 25 mm/min, (*Ra*) is increased with the increase of tool point angle from; 2.5 with tool of point angle (60°) to 4.2, 6.3, 8.1 and 9.6 µm for the others tools (70, 80, 90 and 100°) .The percentage of increase is 35.23 % between the small and big point angle tools when the feed rate is 25 mm/min, but when used feed rate 125mm/min this percentage is changed to 36.45% between them. It is obvious that, the low values of (*Ra*) are shown with the low feed rate values. From the analysis of these results, it can be asserted that, feed rate is the main parameter which effect on the values of (*Ra*) during the drilling operation. The increase of point angle of used tool led to obvious increase in surface roughness (*Ra*). These results demonstrated a strong association between the resultant surface roughness (*Ra*) with feed rate and tool point angle when used fiber orientation angles [0/0/0/0] and cutting speed 3000rpm.

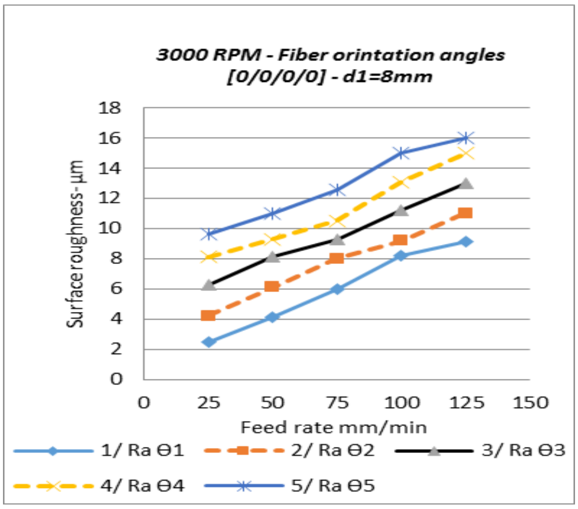

Figure 17: (*Ra* - *f*) Relation at; Five tools of different point angles, Fiber orientation angles [0/0/0/0] and RPM 3000.

In Figure (18), fiber orientation angles is changed to (0/45/45/0) and the other parameters are still as used in Fig. (17). From this figure, (*Ra*) is increased with the increase of feed rate and also with the increase of tool point angle. The values of (*Ra*) is bigger than that when used fiber orientation angles (0/0/0/0) with the same parameters. It evident that, when used fiber orientation angles (0/45/45/0) a bad surface is shown at the drilled hole and this led to an increase in surface roughness (*Ra*) as compared with the previous fiber orientation angles (0/0/0/0) with the same cutting speed 3000 rpm. Also, it can be seen that, fiber orientation angles is the main parameter which effect on the surface roughness (*Ra*) during drilling with these parameters. The increase of point angle of the used tool led to obvious increase in surface roughness in the produced hole. (*Ra*) is increased from; 5.1 to 7.2, 9.1, and 12.0 and to 13.6 µm for feed rate 25mm/ min and with the used tools. In the other side, the surface roughness (*Ra*) is increased from; 5.1 to 6.3, 7.8, and 10 and to 12.0 µm with the used feed rates and tool of point angle (60°).

The percentages of increase due to change of fiber orientation from (0/0/0/0) to (0/45/45/0) and with different used tools and for feed rate 25 mm/min are; 34.21, 26.31, 18.18, 19.4, and 17.24 %.When used feed rate 125mm/min, these values are changed completely and became; 13.74, 13.73, 8.77, 7.12 and 10.11%. The results demonstrated a strong association between the resultant values of surface roughness (*Ra*) with fiber orientation, feed rate and tool point angle for used cutting speed 3000rpm.

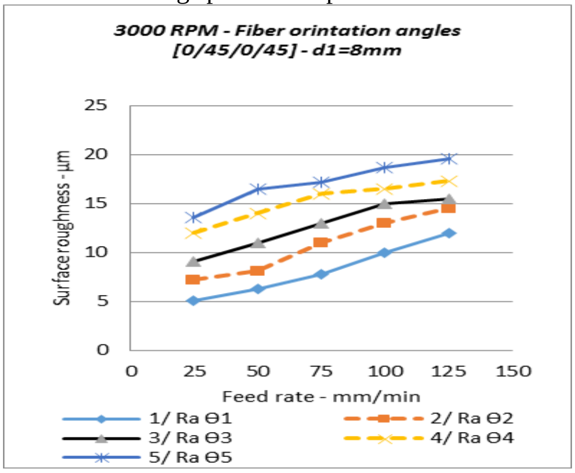

Figure 18: (*Ra* - *f*) Relation at; Five tools of different point angles, Fiber orientation angles [0/45/45/0] and RPM 3000.

The plotted results in Fig. (19) are due to the change fiber orientation angles from (0/45/45/0) to (0/90/90/0) and the other parameters are still as used in previous Fig. (18). (*Ra*) is increased with the increase of both, feed rate and tool point angle. The comparison between the results of the two fiber orientations (0/45/45/0) and (0/90/90/0) is demonstrated that, the change of fiber orientation led to a decrease of surface roughness (*Ra*) with the same cutting speed 3000rpm. The decrease due to change of fiber orientation and for different used tools with feed rate 25 mm/min are; 9.68, 8.27, 6.43, 14.29, and 6.25% respectively. With the tool of point angle (60°) these values are; 9.68, 6.78, 5.41, 5.26 and 7.62% for the five feed rates. For the tool of point angle (70°), the decreases with also used feed rates are; 8.27, 7.28, 10.0, 8.33 and 7.8% and when used biggest tool of angle (100°), the decrease in (*Ra*) values became; 6.25, 8.2, 6.83, 4.76 and 1.55%. It is clear that, the surface roughness values of all used tools are decreased as compared when used fiber orientation (0/45/45/0).

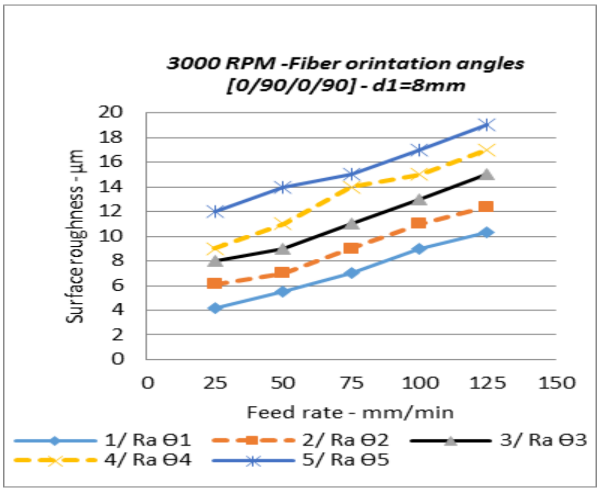

Figure 19: (*Ra* - *f*) Relation at; Five tools of different point angles, Fiber orientation angles [0/90/90/0] and RPM 3000.

From the analysis of these results, it can be asserted that, fiber orientation angles is the main parameter which effect on (*Ra*) during drilling with the used feed rates and the different tools when using cutting speed 3000rpm.

From figures (17, 18 and 19), it can be seen that, when used rpm 3000,the change in average percentages due to change in feed rate between 5 and 125 mm/min with fiber orientation angles (0/0/0/0),(0/45/45/0)and (0/90/90/0) are as follow ;36.45% ,35.02% and 36.28% respectively.

Also, from Figs. (11-19), the change of fiber orientation angles plays a vital role in the resultant (*Ra*). In the following is a comparison between the three sets of fiber orientation angles with different parameters. The average change in (*Ra*) values due to change of the fiber orientation angles with different used tools, feed rate 25 mm/min and 1000 rpm are; 18.02% from (0/0/0/0) to (0/45/45/0) ,11.96% (decreases)due to change from(0/45/45/0) to (0/90/90/0) .But with rpm 2000 the average percentages are; 13.91% and 9.94% with fiber orientation from (0/0/0/0) to (0/45/45/0) and(0/45/45/0) to (0/90/90/0) respectively.

The average percentages of increases in (*Ra*) due to change the fiber orientation angles from (0/0/0/0) to (0/45/45/0) and with different tools, when feed rate 25 mm/min and 3000 rpm are ;5.23% and 3.0% with fiber orientation angles from(0/0/0/0) to (0/45/45/0) and (0/45/45/0) to (0/90/90/0).
With the three cutting speeds, the analysis of results demonstrated a strong association between the resultant of surface roughness (*Ra*) with the feed rate and with all sets of fiber orientations angles (0/0/0/0), (0/45/45/0) and (0/90/90/0) .In the following a comparison between the three sets of fiber orientation angles with different parameters. The average increases in (*Ra*) due to change the fiber orientation angles and with the increase in the point angle of tool from (60°) to (100°) when used feed rate 25 mm/min and 1000 rpm is 17.61% when change fiber orientation from(0/0/0/0) to (0/45/45/0) and 11.42% (decreased) when change fiber orientation from (0/45/45/0) to (0/90/90/0). Also, the average increases in (*Ra*) due to change the fiber orientation angles and with the increase in the point angle of tool from (60°) to (100°) when used feed rate 25 mm/min and 2000 rpm are 5.98% and 19.48% (decreased) when change fiber orientation from (0/45/45/0) to (0/90/90/0). The average increases in (*Ra*) due to change the fiber orientation angles and with the increase in the point angle of tool from (60°) to (100°) when used feed rate 25 mm/min and 3000 rpm are; 9.54% and 4.59%(decreased) when change fiber orientation from (0/45/45/0) to (0/90/90/0).

From the previous figures and the deeply analysis, it obvious that, the surface roughness (*Ra*) is increased with; the increase of feed rates, tool point angles and with change of fiber orientation angles specially (0/45/454/0). But (*Ra*) values are decreased with the increase of cutting speed specially when used the big cutting speed with fiber orientation angles (0/0/0 0). The increase of (*Ra*) with the increase of tool point angle may be due to the increase of friction effect produced by drilled tool at the wall of the hole due to the increase of point angle of the used tool.

The tool geometry have a large influenced on the results both for surface roughness values (*Ra*) and delamination factor (*Ra*) around the hole.

5. Conclusions

The experimental methodology applied in this research to study the influence of drilling parameters; cutting speed, feed rate, tool point angle and fiber orientation angles on the drilled hole quality and also on the result defects associated in the drilling specially the delamination of (GFRP).From the analysis of the results it can be concluded that:

1) The analysis of the results demonstrated a strong association between the resultant of the delamination factor (df) with the feed rate and also with tool point angle when using all sets of fiber orientation angles (0/0/0/0),(0/45/45/0)and (0/90/90/0) with the three cutting speeds.
2) The delamination factor (*df*) is increased with the increase of feed rate and also with the increase of tool point angle.
3) The feed rate and point angle of tool are had a large effect on delamination factor (*df*) and surface roughness (*Ra*) , while both of the delamination and surface roughness are increased with the increase in point angle from 60° to 100°.
4) 4. A decrease in delamination factor values (*df*) when cutting speed decreases and with low feed rates combined with tool point angle (60°) when using all sets of fiber orientation angles and with the three cutting speeds.
5) An increase in delamination factor values (*df*) when cutting speed increases and also when use big feed rates combined with tool point angle (100°).
6) The surface roughness (*Ra*) is increased with both, the increase of feed rate and tool point angle and also, with the change of fiber orientation angles specially with (0/45/454/0).
7) Big cutting speed (3000 rpm), fiber orientation angles (0/0/0/0), low feed rate (25mm/min) and tool point angle of (60°) are suitable for drilling GFRP to get a better surface roughness.
8) The best quality of drilled hole is achieved when feed rate is 25 mm/min and with cutting speed 3000rpm for all fiber orientations used.
9) Surface roughness (*Ra*) values are decreased with the increase of cutting speed specially when used the big cutting speed (3000rpm)with fiber orientation angles (0/0/0 0).

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