Evaluation of the Surface Roughness and the Delamination in Drilling Hole of Al/SiCp MMCs

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Abstract: *In the present research, the analysis of the experimental results has been carried out to study the influence of the following input process parameters; three of the cutting speeds, five of the feed rates and five of the drill tools (HSS - different point angles-same diameter) on the process responses, i.e. the delamination factor (df) and the surface roughness (Ra) of the drilled hole. The drilling has been carried out on the plate of AL/Sicp metal matrix composite MMC, when using three of volume fraction ratios. The analysis of these results indicated that the delamination factor (df) is increased with the increase of; the feed rate, the tool point angle, the cutting speed and with the increase of volume fraction ratios. Also, the surface roughness (Ra) of the drilled hole is increased with the increase of; the feed rate, the tool point angle and with the increase of volume fraction ratios, but decreases with the increase of the cutting speed.*

Keywords: Metal -matrix composites, Defects, Surface Quality, Surface Delamination, Drilling.

1. Introduction

Particulate metal matrix composites (PMMCs) have found wide applications in some industrial fields in which the parts are required to be light and heat resistant or wear resistant. Particularly, non-continuously reinforced materials such as aluminum matrix composites reinforced by silicon carbide particles have become practical engineering materials. It is obvious that drilling of composite materials is a difficult task due to its heterogeneity and the number of problems, such as surface defects, particles pullout associated with the characteristics of the material and the cutting parameters that appear during the machining process. Surface roughness has a great influence on the functional properties of the product and the components surface roughness plays a vital role when these parts are assembled. Friction, wear and power transmission depends on material surface and contact environment. Also, objective consideration may be with respect to the stress condition, precision fits, smooth motion...etc. Finding the rules that how process factors and environmental factors affect the values of the surface roughness will help to set the process parameters of the future and then improve production quality.

S. Senthil Babu, B. K. Vinayagam [1] presented the analysis of various parameters in the drilling of Al/Sic metal matrix composites and Al/Sic/Gr hybrid composites. The used specimens (square slabs) are fabricated by stir casting method which has these dimensions (100× 100× 10mm) and subsequently drilled using CNC vertical machining center with Carbide tipped tool. Taguchi's techniques with L27 orthogonal arrays is used. To correlate various parameters with surface roughness and thrust force, a model is developed using response surface methodology. All the effective parameters are determined using analysis of variance. In the work of S. T. Huang, et al. [2], high-volume-fraction of SiCp/Al composites is used because this kind of composites has excellent thermo-physical properties. The influences of the cutting speed and feed rate on the drilling performance of SiCp/Al composites with 56% of Sic particles are investigated experimentally. Drilling forces, tool wear, and the surface quality of drilled-hole are studied and determined.

From the analysis of the results, it is obvious that the feed rate is one of the main cutting parameters that affect the drilling performance but cutting speed has no significant effect on the thrust force. The analysis and optimization of drilling parameters for tool wear and hole dimensional accuracy of B4C reinforced Al-alloy are presented in the work of A. Taskesen, K. Kutukde [3]. The cutting parameters, which evaluated and optimized are tool wear and size error of drilled hole by used multiple performance characteristics and Taguchi's L27, 3-level, 4-factor orthogonal array for the different tests. Abrasive wear and built up edge (BUE) formation are seen in the tool wear, and the corner wear is also of major importance. According to the experimental results, the tool wear increased with particle mass fraction and decreased with feed rate. The particle mass fraction, followed by feed rate, drill hardness and spindle speed has a major effect on the flank wear of the cutting tool. Cutting speed had less effect on the tool wear than the other machining parameters over the used range of speeds. Higher BUE formation is observed with HSS tools than TiAlN coated carbide tools but uncoated tools are subjected to greater BUE than the coated drills. Also, the produced hole sizes are negatively affected by the tool wear, and the best results are obtained with coated carbide drills. Also, TiAlN coated carbide drills showed the best performance about to the tool wear as well as hole size. These results are estimated by using Grey relational analysis. The largest grey relational grade is found for the B4C particle content of 10 %, and feed rate of 0.3 mm/rev, spindle speed of 1500 rpm and drill material of TiAlN coated carbide. The previous values are the recommended levels of the drilling parameters when the minimization of the tool wear and Diametral error are simultaneously considered. Also, the optimal combination of the drilling parameters could be used to obtain both minimum tool wear and Diametral error. In the research of, Vikas K Doomra, et al. [4], a finite element model has been developed using finite element platform (ABAQUS/Explicit) to simulate the drilling behavior of Al1100/10% Sic metal matrix composite. The effect of two cutting parameters, cutting speed and feed rate on thrust force is studied experimentally. From the results, the thrust force experimentally increases

with an increase in cutting speed and feed rate. Low cutting speed and feed rate should be preferred while drilling Al1100/10% Sic MMCs. A three-dimensional FE model has been proposed for predicting the thrust force during drilling of MMCs and the predicted results have been compared with experimental results. The magnitude of thrust force obtained from the proposed finite element model is in close agreement with the experimental values. The proposed finite element model is quite efficient to predict the thrust force signals generated during drilling of metal matrix composites. The present research of, Sarbjit Singh [5], studied the change in drill point geometry on the drilling quality characteristics of the drilled hole wall for Al-6063/10% Sic MMC using Taguchi design of experiments. The drilling parameters which used are specific cutting pressure and surface roughness of the drilled hole wall. The levels of the input process parameters are established by Taguchi's methodology for optimum values of the output responses. The analysis of the chip formation reveals the cutting mechanism of the primary and the secondary cutting edge of modified drill point geometry is conducted. Single conical chips are produced in the case of primary cutting edge and single ring type of chips is produced in the secondary cutting edge respectively. During drilling with the modified drill geometry, no burr formation is observed either at entrance or at the exit side. Therefore, no additional machining operation is needed and overall cost of production is reducing. The main factor, which influences the specific cutting pressure, is the step diameter followed by feed rate and tool point angle. A large lump of material has been sheared off from cutting zone by the cutting edge at higher feed rate. For this reason, an increase in the energy is transferred from drill point geometry to the workpiece material being sheared and causes an increase in the thrust force and torque values. The burnishing and honing effect produced by the Sic particulates has a vital role in the behavior of surface roughness with respect to process parameters. The variation in the values of cutting forces increases the temperature at the cutting zone and facilitates stable Built up edge (BUE) formation. The burnishing effect produced by entrapped abrasive particles leading to an improvement in the surface finish of the drilled hole wall. The evaluation of the thrust force and surface roughness in drilling of Al/15%Sic/4% Graphite hybrid metal matrix composite is presented by A. Muniaraj, et al. [6]. This hybrid composite is fabricated using stir casting method. The experiments plan is prepared to study the effect of spindle speed and feed rate on the thrust force and surface roughness using coated carbide twist drill and carbide multifaceted drills of 4 mm diameter under various cutting conditions. The results indicated that, coated carbide tool performs better than multifaceted carbide drill in term of improved surface finish of the drilled hole. Micro cracks, particle pull out and shearing of particles are shown in the drilled surface. The feed rate is the main factor, which influence on the thrust force and drilled surface. The increase in the feed rate is led to an increase in the surface roughness values and decreases with the increase in the spindle speed. For all cutting conditions coated carbide tool exhibits higher thrust force when compared with multifaceted carbide drill. In the study of Srinivasan, et al. [7], an attempt has been made to model the machinability evaluation through the response surface methodology in machining of homogenized 10% micron Al2O3 LM25 Al MMC manufactured through stir casting

method. The combined effects of three machining parameters including cutting speed, feed rate and depth of cut on the basis of three performance characteristics of tool wear, surface roughness (Ra) and cutting force are investigated. These parameters are optimized using desirability-based approach response surface methodology. The developed model is used for predicting tool life, surface roughness and cutting force. The optimizing of process parameters gives lower of surface finish and cutting force. The surface roughness is better with increase of the cutting speed whilst increasing feed adversely affects the surface roughness. From the analysis of the results, cutting speed has the most dominant effect on tool wear and the cutting force almost linearly varies with feed rate. The cutting force is higher at low cutting speed and the interactions of cutting speed with feed rate and depth of cut dominantly affects the cutting forces. The developed model has been validated experimentally and exhibit low values of error. Also, R.Venkatesh A., et al. [8], presented a work to overcome the problem of poor machinability of Aluminum Silicon Carbide (A356-Sic) materials. Aluminum A356 is the base matrix material reinforced with 20 % weight by volume of Silicon Carbide particles of mean diameter 55 μm to 80 μm is used. Minimum power consumed by main spindle, less surface roughness and minimum tool wear are the major parameters which be investigated. Due to the stability of the tool at higher cutting speed and easy removal of material, the surface finish is better at this stage. The (PCD) tool of grade 1300 performs well in metal removal rate, but wear is more. The use of low feed (0.108 mm/rev) has resulted decrease in cutting force and when using high feed rate of (0.368 mm/rev) with high depth of cut has resulted good amount of metal removal. The Increase in cutting speed improves surface finish, and as the feed rate increases, surface finish improves only up to certain level after that it starts deteriorates. A.Muniaraj, et al. [9] presented a study on the Influence of drilling parameters on thrust force when drilling of Sic and graphite reinforced aluminum matrix composites by step drill. The experiments of this work are conducted to study the effect of spindle speeds (1000, 2000 and 3000 rpm), feed rates (0.05, 0.10 and 0.15 mm/rev) and different diameter of drills (4 , 8 and 12 mm) with dry drilling and TiN coated solid carbide step drills. To study the influence of cutting parameters on drilling of hybrid metal matrix composites, computer numerical control machining center is used. From the analysis of the experimental results, feed rate is the main factor, which influence the thrust force, and also affects drilling forces but cutting speed has not much effect over the range of spindle speeds. The increase in cutting speed is led to a decreases in thrust the forces. The coating material of the used tool is removed due to the abrasive action of the SiC particles. Studying and comparing the machinability aspects of B4Cp reinforced 6061Al alloy MMC reinforced with 37μm and 88μm particulates produced by stir casting method is presented by Vijaykumar Hire math, et al. [10]. To identify morphology and distribution of B4C particles in the matrix of 6061Al, the composite is prepared using Scanning Electron Microscopy equipped with EDX analysis (Hitachi Su–1500 model). Using a (PCD) tool to study the effect of particle size on the cutting forces and the surface roughness under varying machinability parameters viz. two of cutting speed, feed rate and depth of cut. From the results, good uniform distribution of B4C particulates in

6061Al matrix is achieved due to the addition of K2TiF6 halide salt. The surface roughness of the composite is influenced by cutting speed and also, surface roughness is high with 88μm particle reinforced composites and when the particle size increases surface roughness also is increased. Sarbjit Singh, et al. [11] presented a study on the optimization of the process parameters for drilling of (MMC) using Taguchi techniques. The aims of the present investigations is to studying the effect of drilling parameters (cutting speed, feed rate and the drill point geometry) on the output responses such as, thrust force, specific cutting pressure and surface roughness. The technique of Taguchi is applied to obtain an optimal setting for drilling process parameters for optimizing the output quality characteristics. The analysis of the results indicated that, the effect of cutting speed on the thrust force shows a quadratic behavior, it increases with increase in cutting speed and then decreases. Also, thrust force is varies with different drill point geometry and the Jo-drill point shows a minimum value of thrust force. The specific cutting pressure is increased with the increase in the cutting speed and decreases with the increase in feed rate. The precipitous decrease in specific cutting pressure shows when used Jo-drill point than four facet and parabolic drill point geometry. The contribution percentage of process parameters while predicting specific cutting pressure are, cutting speed (Insignificant), feed rate (53%) and drill point geometry (38%). The surface roughness decreases at higher cutting speed due to the honing effect produced by the entrapped abrasive particles. The contribution percentages of process parameters while predicting surface roughness are, cutting speed (16%), feed rate (31%) and drill point geometry (47%). Effect of cutting parameters on thrust force, surface roughness and burr height during drilling of the pure base alloy (Al-2219), mono composite (Al- 2219+8%B4C) and hybrid composite (Al-2219+8%B4C+3%Gr) MMCs is investigated in the work of, V M Rabindranath,et al. [12]. The drilling is conducted on CNC machine with TiN coated HSS tool, M42 (Cobalt grade) and carbide tools at various spindle speeds and feed rates. From the experimental results, the feed rate has more influence on thrust force and surface roughness. The Less values of thrust force and discontinuous chips are produced during drilling of hybrid composites when compared with mono and base alloy during process. It is may be due to the solid lubricant property of graphite which reduces the thrust force, burr height and lower surface roughness. Better surface finish is obtained with Carbide tool at low feed rate and high spindle speeds compared to other two types of cutting tool materials. The surface roughness is increased with the increase of feed rate and decreases with the increase of cutting speed. It is obvious that, when machining hybrid composites, a poor surface finish is obtained due to graphite particle pull out from the drilled surface. When compared the height of exit burr for different types of drill tools, it is less during drilling Graphitic composites. The chip formed of hybrid composites are of discontinuous type, and it is easier for chip disposal. In the paper of T. Rajmohan, K. Palanikumar [13], the modeling and analysis of machining responses such as the thrust force, surface roughness, burr height, and tool wear in the drilling of Al 356 aluminum alloy reinforced with silicon carbide of size 25 μm and mica of size 45 μm using carbide, coated carbide, and polycrystalline diamond drills is presented. The chosen of numerical factors are, spindle speed, feed rate, and weight percent of silicon carbide and the drill material is considered as the categorical factor. D-optimal design based on the response surface methodology is employed to carry out the experimental study. From the results, the predicted values through the developed model are well in agreement with the experimental results. Also, the feed rate is the highly influential parameter which influences the thrust force, surface roughness, tool wear, and burr height (exit) in the drilling of hybrid metal matrix composites. PCD drilling tool performs better than the other tools in terms of improved surface finish and reduced thrust force, tool wear, and burr height in the drilling of composites. The increase in both of feed rate and spindle speed increases the tool wear and vice versa. ANOVA results indicated that, the experimental data are well correlated with the predicted results at 95 % confidence interval. Therefore, the used technique can be very useful for a reliable prediction of different performances. Hari Singh, et al. [14], presented a study on Multi Response Optimization in drilling of Al6063/SiC/15% MMC. The output response are, surface roughness, burr height and the error in hole diameter under the experimental conditions of cutting speed ,feed rate, step angle, and cutting environment. By using L27 orthogonal array, the drilling experiments are conducted on these composites using high-speed steel step drill bits. A combination of three techniques (orthogonal array, design of experiments and grey relational analysis) are ascertain best possible drilling process parameters that give minimum surface roughness, burr height and the error in hole diameter. The optimal level of process parameters are, cutting speed of 150.72 m/min, feed rate of 0.05 mm/rev, step angle of 90° and cutting environment of water soluble oil. The results when used the Analysis of Variance Method indicated that, feed rate has maximum influence (60.59%) followed by step angle (19.07%) and cutting speed (11.48%) in affecting the drilling of composites and the interaction of cutting speed and feed is found be significant (4.98%). The modeling of the drilling process for aluminum composites using Multiple Regression Analysis and Artificial Neural Networks is presented by Ahmad Mayyas, et al. [15]. The modeling of the machinability of self-lubricated aluminum /alumina/graphite hybrid composites synthesized by the powder metallurgy method is investigated in this work. Multiple regression analysis (MRA) and artificial neural networks (ANN) are used to investigate the influence of some parameters on the thrust force and torque in the drilling processes of self-lubricated hybrid composite materials. The two methods, which used in prediction, are showed that, Al2O3, Gr and cutting feed (f) are the most significant parameters on the drilling process, while spindle speed seemed insignificant. Modeling methods revealed that, reinforcement fractions are the important factors that influence the responses (i.e. thrust force and torque) followed by the feed rate. The used ANN models showed a close matching between the model outputs and the measured outputs, and the values of mean absolute relative errors are (2.89%) thrust force models, (0.82%) for torque while MRA model error values are (7.10%) and (12.59%), respectively. From the analysis, the models can be used efficiently for prediction potentials for non-experimental patterns, which, in turn, save experimental time and cost and the ANN methodology consumes less time and gives higher accuracy.

From the study of the previous literature review, this field need more researches and studies to understand and analyze the behavior of various defects especially the surface roughness and delamination with different cutting parameters and different conditions of drilling accurately. During machining of MMCs, many factors affect the surface roughness and delamination in the drilled hole. Feed rate and cutting speed are the important factors, which affect the quality of drilled hole. Volume fraction ratio and particles size of reinforced material are another important factors, which affected the quality of drilled surfaces. Therefore, the independently controllable drilling parameters that are having large influences on the surface roughness and delamination in the drilled hole of AL/SiCp (MMCs) specimen has been identified. These parameters are; i) cutting speed, ii) feed rate, iii) tool geometry and volume fraction ratio is used in this investigation.

2. Experimental work
2.1. Materials, Tools and Used parameters

Aluminum 1050 is the base matrix material reinforced with 15, 25 and 35 % of Silicon carbide particles of mean diameter 88 μm is used. The composite is produced by stir casting technique. The experiment have been carried out on the plate (200 x40 x 20 mm). Five tools of different point angles twist drills made of high-speed steel (HSS), φ 12 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 are listed in Table (1). The specifications of the used drilling machine are listed in Table (2).

Table (1): The levels used of identified factors.

Parameters	The used levels				
Feed rate, mm/min	15	30	45	60	75
Tool point angle of the Tools	60°	70°	80°	90°	100°
Cutting speed, rpm	500 ,1500 ,2500				
Volume fraction %	15, 25, 35				
Particle size μm	88				

Table (2).Specifications of the drilling machine.

Model	Drilling Capacity	Face Milling Capacity	End Milling Capacity	Voltages
ZX7032	31.5mm	80mm	22mm	380/50HZ/1500W
Speeds	300,...,...,700,…,1000,…,1200,...,1500,..,1700 and…. 2500 ,…..etc. RPM			

2.2. The Surface roughness measurement of the machined holes

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.

3. Results and Discussion

The analysis of the experimental results has been carried out to study the influence of the following input process parameters; three of cutting speeds 500, 1500 and 2500 rpm), five of feed rates (15,30,45,60 and 75mm/min) and five of the drill tools (HSS - different point angles 60, 70, 80, 90 and 100°-φ 12mm) on the process responses, i.e. the delamination (df) and surface roughness (Ra) of the drilled hole (when using three of volume fraction ratios 15, 25 and 35 %). From the deeply study of the previous work, it is recommended that, the proposed methodology of experiments is suitable for analysis the delamination and surface roughness at drilling of MMC. In the assessment of the delamination (df) and surface roughness (Ra) all the estimated ratios with respect to the results when used feed rate 15 mm/min and tool of point angle (60°).

3.1. Assessment of delamination (df) and surface roughness (Ra)
3.1.1. RPM 500 and Vf 15%

In Figure (1), the relation between the feed rate (f) and the delamination factor (df) with the three drilling parameters is plotted. These parameters are; the cutting speed (500 rpm), five of feed rates [15, 30, 45, 60 and 75 mm/min-(f)], five tools of different point angles (60, 70, 80, 90 and 100°) and with volume fraction ratio 15%. From this figure, the delamination factor (df) is increased with the increase of the feed rate and also increases with the increase of the tool point angle. The ratios of increase in (df) when used tool of point angle (60°) are, 0.32, 0.43, 0.54 and 0.65 % with the four feed rates (30, 45, 60 and75 mm/min). Also, with feed rate 15 mm/min, it is increased from; 0.34 % with tool of point angle (70°) to; 0.45, 0.57 and to 0.67 % for the other tools (80, 90 and 100°) respectively. When used feed rate 30 mm/min, the (df) is increased from; 0.32% with the tool point angle (60°) to; 0.46, 0.58 and 0.65 and to 0.70 % for the other four used tools. And for the other used feed rates 45, 60 and 75 mm/min, the ratios of increase is between; 0.38 and 0.54 % with the tool of point angle (70°). But for the tool of bigger point angle (100°), the values of (df) are; 0.55, 0.69 and 0.71% for the three feed rates. It is obvious that, the low values of (df) are shown with the low feed rate values. The increase of point angle of the used tool is led also to obvious increase in the delamination factor (df). From the results in figure (1), it can be seen that, the feed rate is the main parameter, which effect on the delamination factor during drilling. Also, these results asserted that, the tool point angles had a large effects on the delamination factor during drilling MMC when using the mentioned parameters.

In Figure (2), the relation between the feed rate (f) and the surface roughness (Ra) with the same drilling parameters that are used in the previous figure. From the results shown in this figure, the surface roughness (Ra) is increased with the increase of the feed rate and increases with the increase of the tool point angle. The surface roughness (Ra) is increased between, 4.0 and 13 μm for the used feed rates and with the tool of point angle (60°). With feed rate 15 mm/min, (Ra) is

increased from; 4.0 µm with the tool of point angle (60°) to; 6.0, 9.0, 11 and 13 µm for the others used tools (70, 80, 90 and 100°). For the other used feed rates, 30, 45, 60 and 75 mm/min, the ratios of increase in (Ra) are; 2.0, 2.2, 2.4 and 2.8 % with tool of (70°) and with tool of (80°) point angle, the values of (Ra) are changed to; 2.2, 2.4,2.8 and 2.9%. When used tool of point angle (90°), the ratios of increase in (Ra) are; 2.8, 3.3, 3.9 and 4.3 % and with the tool of point angle (100°), the ratios of increase are; 3.3, 3.8, 4.1 and 4.5% for feed rates 30, 45, 60 and 75 mm/min. It is obvious that, the feed rate and the tool point angle are the dominant factors that influence in (Ra) during drilling of MMC at the used parameters.
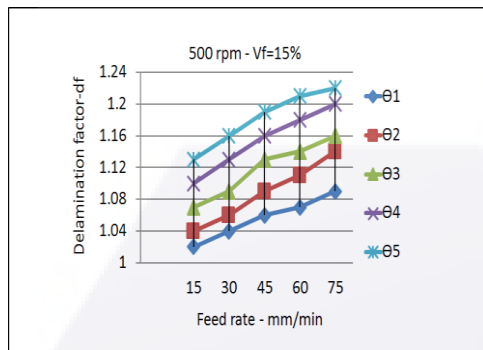
Figure 1: (df - f) Relation at; Vf =15%, RPM 500 and five tools of different point angles.
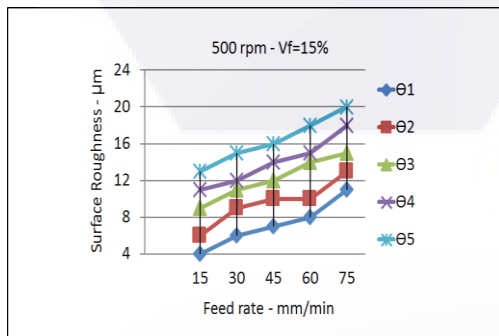
Figure 2: (Ra- f) Relation at; Vf =15%, RPM 500 and five tools of different point angles.

3. 1.2.RPM 500 and Vf 25%

The relation between the feed rate (f) and the delamination factor (df) with the same drilling parameters which are used in the previous figure is plotted in Fig. (3), but the volume fraction ratio is changed to 25%. The delamination factor (df) is increased with the increase of the feed rate and also with the increase of the tool point angle as shown in this figure. The ratios of increase in (df) when used tool of point angle (60°) are; 0.36, 0.47, 0.50 and 0.60 % with the four feed rates (30, 45, 60 and75 mm/min) .Also, with feed rate 15 mm/min, it is increased from; 0.38 % with tool of point angle (70°) to 0.49, 0.61 and to 0.71 % for tools (80, 90 and 100°) respectively. For feed rate 30 mm/min, the (df) is increased from; 0.36% with tool point angle (60°) to 0.50, 0.62, and 0.72 and to 0.74 % for the four used tools. For the other used feed rates, the ratios of increase are; 0.42 ,0.50, and 0.65 % with tool of (70°) point angle and with tool of (80°) the

values are changed to ;0.57,0.62 and 0.66 % . But for the tool of bigger point angle (100°), the increase in (df) ratios are; 0.63, 0.72 and 0.75 % for the feed rates (45, 60 and 75 mm/min). From the comparison between the results when using ; the five used tools , (Vf-15%) and cutting speed 500 rpm with the results in Fig.(3) when used the same parameters but (Vf) is changed to 25%, it is clear that, the change of (Vf) leads to an increase in all values of (df). The ratios of increase in (df) when used feed rate 15 mm/min and with the five used tools are; 1.09, 1.11 1.12, 1.13 and 1.14 % respectively. Also, with the bigger feed rate 75 mm/min and with the used tools, the ratios of increase in (df) are; 1.13, 1.16, 1.20, 1.22 and 1.25 %. It is obvious that, from this comparison, the values of (df) are increased with the increase of the feed rate and also with the increase of the point angle of the used tool between (VF, 15% and 25%) with the same cutting speed 500 rpm. It has been observed that, the low feed rate (15mm/min) and the tool of small point angle (60°) are gave a less values of delamination factor during drilling when using volume fraction of 25% and with cutting speed 500 rpm.

In Fig. (4), the increase in the feed rate leads to an increase in the surface roughness of machined hole. The surface roughness (Ra) also increases with the increase of tool point angle. The average increase in the surface roughness (Ra) is between, 11 and 18 µm for the feed rates (30, 45, 60 and75 mm/min) and with tool of point angle (60°). With feed rate 15 mm/min, the ratios of increase in (Ra) are from; 2.2 % with tool of point angle (70°) to 2.7, 3.2, and 3.7% for the others used tools. When used feed rate 30 mm/min, the (Ra) is increased from; 2.6 % with tool point angle (70°) to 3.1, 3.6 and 4.1 % for the other three used tools. The ratios of increase in (Ra) for the other feed rates 45, 60 and 75 mm/min are; 3.4, 3.9 and 4.4 % with tool of (70°) and with tool of (80°) point angle the values are changed to; 3.6, 4.1 and 4.6 % . For the tool of point angle (90°), the values are; 3.8, 4.3 and 4.8 %. When used the tool of point angle (100°), the increased ratios of (Ra) are; 4.1, 4.6 and 5.1% for the same feed rates. It is obvious that, the used in volume fraction ratio to 25% with the same used parameters, is led to an increase in the values of surface roughness (Ra). Also, the feed rate and the tool point angle are had large effect on the resultant values of the surface roughness (Ra) at the used parameters. From the comparison between the results when using; the five used tools, (Vf-15%) and cutting speed 500 rpm, with the results in Fig. (4) When used the same parameters but the volume fraction (Vf) is changed to 25%, the analysis of these results indicated that; the change of (Vf) from 15 to 25% leads to an increase in all values of the surface roughness (Ra). The ratios of increase in (Ra) when used feed rate 15 mm/min and with the five used tools are; 1.04, 1.05, 1.06 and 1.07 and to 1.08 %. With feed rate 75mm/min and the five used tools, the ratios of increase in the surface roughness (Ra) are; 1.71, 2.18, 2.34 and 2.39 and to 2.6% respectively. It is clear that, from this comparison, the values of increase in (Ra) are increased with the increase of feed rate and with the increase of the point angle of the used tools between (VF, 15 and 25%) with the same cutting speed 500 rpm.
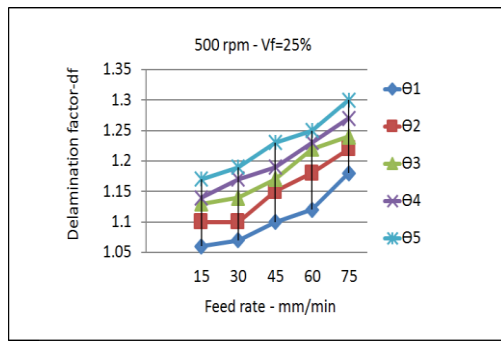
Figure 3: (df - f) Relation at; Vf =25%, RPM 500 and five
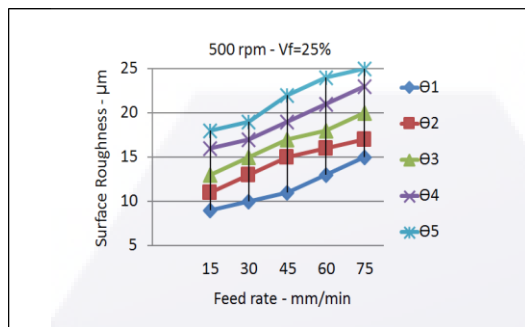tools of different point angles.

Figure 4: (Ra - f) Relation at; Vf =25%, RPM 500
and five tools of different point angles.

3. 1.3. RPM 500 and Vf 35%

In Figure (5), the volume fraction ratio is changed from, 25 to 35%. In this figure, the delamination factor (df) is increased with the increase of feed rate and also increases with the increase of tool point angle. The ratios of increase in (df) is between; 0.39 and 0.72 % when used tool of point angle (70°) and with the four feed rates (30, 45, 60 and75 mm/min). The ratios of increase with the used feed rates is between; 0.49 and 0.74 % when used the tool of point angle (80°). With tool of point angle (90°), it is increased between; 0.55 and 0.78 %. But for the tool of point angle (100°) with the same feed rates, the ratios are changed to; 0.68 to 0.69, 0.72, 0.76 and 0.79 %. It is obvious that, the volume fraction ratio, feed rate and tool point angle are the dominant factors that influence in the resultant values of the delamination factor (df) at the used parameters. It has been observed that, the low feed rate (15mm/min) and the tool of small point angle (60°) are gave a less values of (df) during drilling when using volume fraction of 35% with cutting speed 500 rpm. The change of (Vf) from 15 to 35% when used the same parameters with cutting speed 500 rpm leads to an increase in all values of (df). The ratios of increase in (df) when used feed rate 15 mm/min and with the five used tools are; 1.02, 1.05, 1.13 and 1.14 and to 1.15 %. Also, with the feed rate of 75mm/min and the same used tools, the ratios of increase in (df) are; 1.11, 1.30,

1.33 and 1.34 and to 1.48 % respectively. It is clear that, from this comparison, the ratios of increase are more with the increase of the feed rate and also with the increase of the point angle of the used tools between (VF, 15 and 35%) with the same cutting speed 500 rpm.
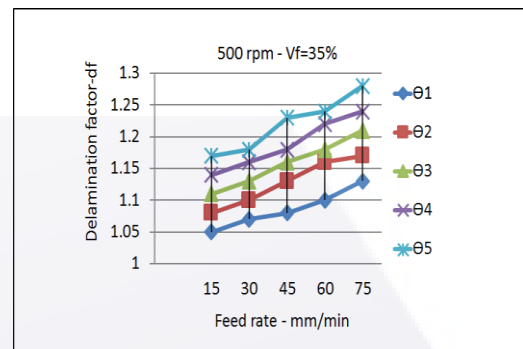

Figure 5: (df - f) Relation at; Vf =35%, RPM 500
and five tools of different point angles.

From Figure (6), it can be seen that, the surface roughness (Ra) is increased with the increase of feed rate and increases with the increase of tool point angle. When used feed rates (30, 45, 60 and75 mm/min) with tool of point angle (60°), the average increase in (Ra) is between; 10 and 15 μm. With feed rate 15 mm/min, the average increase in (Ra) with the increase of tool point angle is between; 9.0 to 19 μm. The average increase in (Ra) with the increase of tool of point angle are from; 13 to 16 and 17 and to 20 μm for the used tools and with feed rate 30 mm/min. For the other used feed rates (45, 60 and 75 mm/min), the average increase in (Ra) is between; 12 to 15μm with the tool of (60°) and 15 to17 μm with the tool of (70°) point angle. The ratios of increase in (Ra) when used the tool of point angle (80°) are; 3.8, 4.3 and 4.8 % and for the tool of point angle (90°), the values are changed to; 4.1, 4.5 and 5.1% for the same feed rates 45, 60 and 75 mm/min. When used the tool of point angle (100°), the ratios of increase in (Ra) are; 4.4, 4.9 and 5.4 % for the same three feed rates. It is obvious that, the feed rate and tool point angle are had most dominant influence in the resultant values of surface roughness (Ra) at the used parameters. The change of volume fraction ratio from 25 to 35% with the same used parameters is led to an increase in the values of surface roughness (Ra).

The change of (Vf) from 15 to 35% when used the same parameters with cutting speed 500 rpm leads to an increase in all values of the surface roughness (Ra). The percentages of increase in (Ra) when used feed rate 15 mm/min and with the five used tools are; 1.17, 1.18, 1.27 and 1.29 and to 1.45%. With feed rate 75mm/min and the five used tools, the ratios of increase in the surface roughness (Ra) are; 1.19, 1.2, 1.61and 1.66 and

to 1.68 % respectively. It is clear that, from this comparison, the ratios of increase in (Ra) are increased with the increase of the feed rate and also with the increase of the point angle of the used tools and between (VF, 15 and 35%) with the same cutting speed 500 rpm.
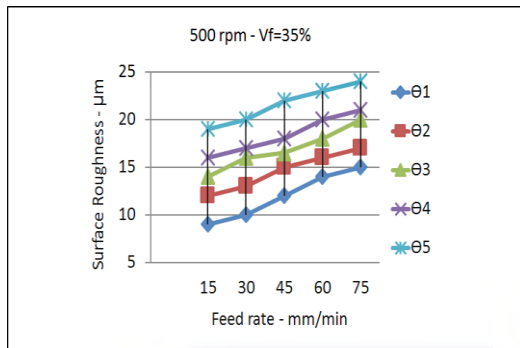

Figure 6: (Ra - f) Relation at; Vf =35%, RPM 500 and five tools of different point angles.

3. 2. RPM 1500 and Vf 15%

From Figure (7), the delamination factor (df) is increased with the increase of feed rate and also increases with the increase of tool point angle. The ratios of increase in (df) when used feed rate 15 mm/min is between; 0.49 % with tool of point angle (70°) to 0.52, 0.64, and to 0.72 % for the others tools (80, 90 and 100°). For feed rate 30 mm/min, the (df) is increased from; 0.38 % with tool point angle (60°) to 0.52 and 0.64, 0.74 and to 0.76% for the other used tools. For the feed rates (45, 60 and 75 mm/min), the ratios of increase in (df) are; 0.44 and 0.52 and 0.67% with tool of (70°) and with tool of (80°) point angle these ratios are changed to; 0.59, 0.64 and 0.68%. When used the tool of point angle (100°), the ratios of increase in (df) are; 0.65, 0.74 and 0.78% for the same feed rates. In the other side, the comparison between the results when used cutting speed 500 rpm, the five used tools , feed rate 15 mm/min and (Vf = 15%) with the same parameters but the cutting speed is changed to 1500 rpm, the analysis indicated that, the increase in cutting speed leads to an increase in the delamination factors(df) . The ratios of increase are; 1.11% with the tool of point angle (60°) to 1.15, 1.16 and 1.28 and to 1.34% for the other four tools (70, 80, 90 and 100°).with feed rate 75 mm/min and the same parameters, the ratios of increase in (df) are; 1.13, 1.19, 1.24 and 1.33 and to 1.38% for the used tools. It is obvious that, the feed rate and the point angle of the tool are play an important role in the resultant values of delamination factor (df) at the used parameters. The change of cutting speed from 500 to 1500rpm with the same volume fraction ratio 15% is led to obvious increase in the values of delamination factor (df).
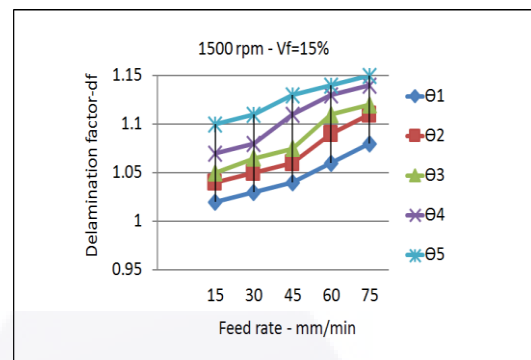

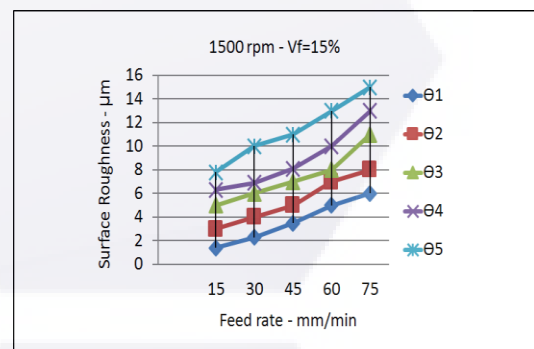Figure 7: (df - f) Relation at; Vf =15%, RPM 1500 and five tools of different point angles.

Figure 8: (Ra- f) Relation at; Vf =15%, RPM 1500 and five tools of different point angles.

From Figure (8), the ratios of increase in (Ra) with the increase of tool point angle are from; 2.0 % with tool of point angle (70°) to; 2.2, 2.6 and 3.0 % for the others tools and with feed rate 15 mm/min. When used feed rate 30 mm/min, (Ra) is increased also from; 2.3 % with tool point angle (70°) to 2.5, 2.7and 3.2 % for the other three used tools. For the other used feed rates 45, 60 and 75 mm/min, the ratios of increase in (Ra) are changed to; 2.3 , 2.4 and 2.7 % with tool of (70°) and 2.4,2,7 and 2,8 % with tool of (80°) point angle respectively. For the same feed rates and with the tool of point angle (90°), the ratios of increase in (Ra) are; 3.6, 3.9 and 4.2% and changed to; 3.9, 4.2 and 4.3 % When used tool of point angle (100°). In the other side, the comparison between the results when used (Vf = 15%) and the cutting speed is changed from 500 to 1500 rpm with the same parameters, the analysis indicated that, the increase in the cutting speed leads to a decrease in (Ra). The ratios of decrease in (Ra) are; 0.71% with tool of point angle (60°) to 0.82, 0.83, 0.88 and 0.97% for the other used tools. And with feed rate 75 mm/min and the same parameters, the ratios of decrease in (Ra) are; 0.94, 0.95, 0.96 and 0.97and to 0.99 % for all used tools. It is obvious that, the cutting speed has more influence in the resultant values of surface roughness (Ra) at all used parameters. Also, the results

in the previous figure demonstrated a very strong association between the resultant surface roughness (Ra) with, feed rate and the tool point angle when change cutting speed from 500 to 1500 rpm.

3. 2.1. RPM 1500 and Vf 25%

In Figure (9), the volume fraction ratio (Vf) is changed from, 15 to 25%. With feed rate 30 mm/min, the ratios of increase in (df) are from; 0.54 with tool of point angle (70°) to 0.55, 0.64 and 0.72 % for the other used tools. For the other used feed rates 45, 60 and 75 mm/min, the ratios of increase is between; 0.56 and 0.69 % with tool of (70°) and 0.61 and 0.73 % with tool of point angle (80°). For the same feed rates, the ratios of increase when used tool of point angle (100°) are; 0.67, 0.76 and 0.81 %. The change of (Vf) from 15 to 25% when used the same parameters with cutting speed 1500 rpm leads to an increase in all values of (df). The ratios of increase in (df) when used feed rate 15 mm/min and with the five used tools are; 1.01, 1.02, 1.03 and 1.04 and to 1.06 %. Also, with the feed rate of 75mm/min and the five used tools, the ratios of increase in the delamination factor (df) are1.03, 1.04, 1.05 and 1.07and to 1.12 % respectively.
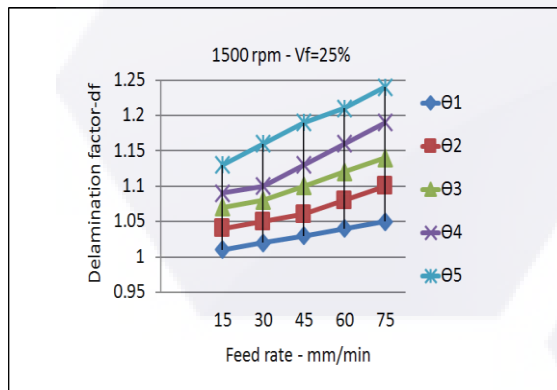

Figure 9: (df - f) Relation at; Vf =25%, RPM 1500 and five tools of different point angles.

In the other side, the comparison between the results when used cutting speed 500 rpm, the five used tools, feed rate 15 mm/min and (Vf) 25% with the same parameters when used cutting speed 1500 rpm, the analysis indicated that, the increase in cutting speed leads to an increase in (df) . The ratios of increase in (df) are, 1.04 % with tool of point angle (60°) to 1.06, 1.06 and 1.12 and to 1.28% for the other four tools (70, 80, 90 and 100°). Also, with feed rate 75 mm/min and the same parameters, the ratios of increase in (df) are; 1.07, 1.08, 1.10, 1.22 and 1.34 % for the uses tools.

From the analysis, the values in the delamination factor (df) are increased with the increase of the feed rate and also with the increase of the point angle of the used tools when changed cutting speed from 500 to 1500 rpm with volume fraction ratio (VF= 25%) .

In Figure (10), the increase in the feed rate leads to an increase in the surface roughness of machined hole, and surface roughness (Ra) also increases with the increase of tool point angle. With feed rate 15 mm/min, the ratios of increase in (Ra) are from; 2.1 % with tool of point angle (70°) to 2.6, 3.1 and 3.6 % for the others used tools. When used feed rate 30 mm/min, the ratios of increase are changed

to; 2.2, 2.6 and 3.2 and to 3.7% for the four used tools. The ratios of increase in (Ra) for the other used feed rates 45, 60 and 75 mm/min are; 3.1, 3.5 and 4.5 % with tool of (70°) and 3.2, 3.6 and 4.6 % with tool of (80°). For the tools of point angles (90°and 100°), the increase in (Ra) are; 3.4, 3.8 and 4.7% and 3.6, 3.9and 4.8% for the three feed rates. The change of (Vf) from 15 to 25% when used the same parameters with cutting speed 1500 rpm leads to an increase in all values of the surface roughness (Ra). The ratios of increase in (Ra) when used feed rate 15 mm/min and with the used tools are; 1.03, 1.04, 1.05, 1.08 and 1.11 %. With the feed rate of 75mm/min and the five used tools, the ratios of increase in (Ra) are changed to; 1.04, 1.06, 1.07, 1.09 and 1.13 % respectively. From the analysis of these results and from this comparison, It is clear that, the ratios of increase in (Ra) are increased with the increase of feed rate and also with the increase of point angle of the used tools between (VF,15 and 25%) with the same cutting speed 1500 rpm.

In the other side, the comparison between the results when used cutting speed 500 rpm, the five used tools , feed rate 15 mm/min and (Vf = 25%) with the same parameters when used cutting speed 1500 rpm, the analysis indicated that, the increase in cutting speed leads to a decrease in the surface roughness (Ra). The ratios of decrease in (Ra) are; 0.62 % with tool of point angle (60°) to 0.64, 0.65, 0.67 and 0.69 % for the other used tools. And with feed rate 75 mm/min and the same parameters, the ratios of decrease in (Ra) are; 0.70, 0.81, 0.86, 0.87and 0.95% for all used tools.
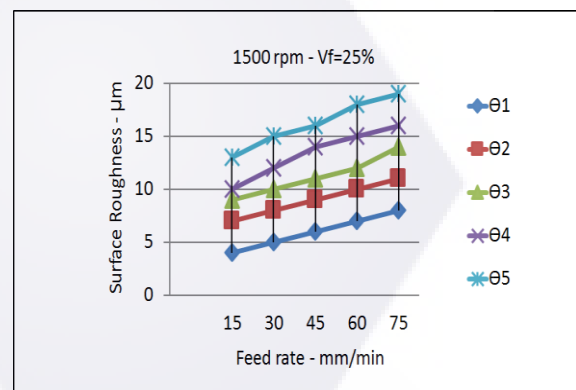

Figure 10: (Ra- f) Relation at; Vf =25%, RPM 1500 and five tools of different point angles.

3. 2.2. RPM 1500 and Vf 35%

In Figure (11), the volume fraction ratio is changed to 35%. From this figure, the delamination factor (df) is increased with the increase of the feed rate and also increases with the increase of tool point angle. The average increase in (df) is between; 1.02 and 1.09 for the used feed rates and with tool of point angle (60°). With feed rate 15 mm/min, the average increase is between; 1.02 to 1.18 for the used tools (60, 70, 80, 90 and 100°). When used feed rate 30 mm/min, the ratios of increase in (df) are from; 0.46 % with tool point angle (70°) to 0.57 and 0.68 and to 0.78 % for the other used tools. For the other used feed rates 45, 60 and 75 mm/min the ratios of increase in (df) are; 0.50, 0.57 and 0.73% with tool of (70°) and with tool of (80°) point angle, the values are changed to; 0.65, 0.70 and 0.75 % with the same three feed rates, and for the tool of point angle (90°), the values are; 0.69, 0.74 and 0.79 %. When used tool of point angle

(100°), the values are changed to; 0.75, 0.80 and 0.85 %for the three feed rates 45, 60 and 75 mm/min. The change of volume fraction ratio from 25 to 35% with the same used parameters, is led to an increase in the values of delamination factor (df). Also, the feed rate and the tool point angle are the most significant factors which affect in the values of delamination factor (df) at the used parameters. Also, the change of (Vf) from 15 to 35% when used the same parameters with cutting speed 1500 rpm leads to an increase in all values of (df). The ratios of increase in (df) when used feed rate 15 mm/min and with the five used tools are; 1.02, 1.04, 1.05, 1.11 and 1.15%. Also, with the feed rate of 75mm/min and the five used tools, the ratios of increase in (df) are; 1.05, 1.07, 1.09, 1.19 and 1.21% respectively. From the analysis, the values of increase in (df) are increased with the increase of feed rate and also with the increase of the point angle of the used tools between (VF, 15 and 35%) with the same cutting speed1500 rpm.

In the other side, the comparison between the results when used cutting speed 500 rpm, the five used tools, feed rate 15 mm/min and (Vf)is changed to 35% with the same parameters when used cutting speed 1500 rpm, the analysis indicated that, the increase in cutting speed and (Vf) are led to an increase in the delamination factors(df) . The ratios of increase in (df) are; 1.04 % with tool of point angle (60°) to 1.06, 1.09, 1.13 and 1.15% for the other four tools (70, 80, 90 and 100°). Also, with feed rate 75 mm/min and the same parameters, the ratios of increase in (df) are; 1.10, 1.24, 1.28, 1.30 and 1.32 % for the uses tools.
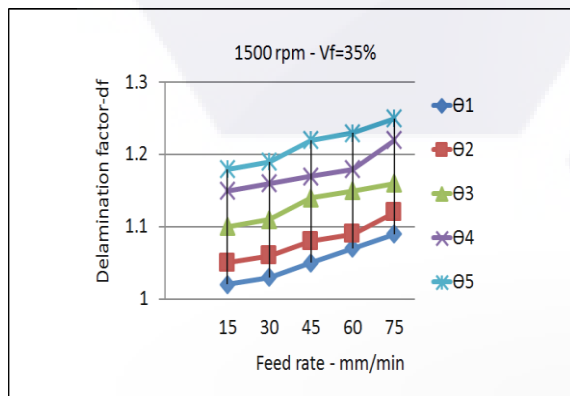
4.0 %. When used tools of point angles (90°and 100°), the values are; 3.9 and 4.7 % and 4.1 and 4.9 % for the two feed rates 60 and 75 mm/min. The change of volume fraction from 25 to 35% with the same used parameters is led to an increase in the values of (Ra). Also, the feed rate and tool point angle are had dominant influence in the resultant values of (Ra) at the used parameters. The change of (Vf) from 15 to 35% when used the same parameters with cutting speed 1500 rpm leads to an increase in all values of the surface roughness (Ra). The ratios of increase in (Ra) when used feed rate 15 mm/min and with the used tools are; 1.02, 1.03, 1.05, 1.07 and 1.09 %. Also, with feed rate 75mm/min and the five used tools, the ratios of increase in (Ra) are changed to; 1.03, 1.07, 1.12, 1.17 and 1.25% respectively. From the analysis of this comparison, the ratios of increase in (Ra) are increased with the increase of the feed rate and with the increase of the point angle of the used tools between (VF, 15 and 35%) with the same cutting speed1500 rpm. In the other side, the comparison between the results when used cutting speed 500 rpm, the five used tools , feed rate 15 mm/min and (Vf = 25%) with the same parameters when used cutting speed 1500 rpm, the analysis indicated that, the increase in cutting speed leads to a decrease in the surface roughness (Ra). The ratios of decrease in (Ra) are; 0.62% with tool of point angle (60°) to 0.67, 0.68, 0.72 and 0.74% for the other used tools. With feed rate 75 mm/min and the same parameters, the ratios of increase in (Ra) are; 0.70, 0.81, 0.86, 0.89 and 0.95 % for all used tools.
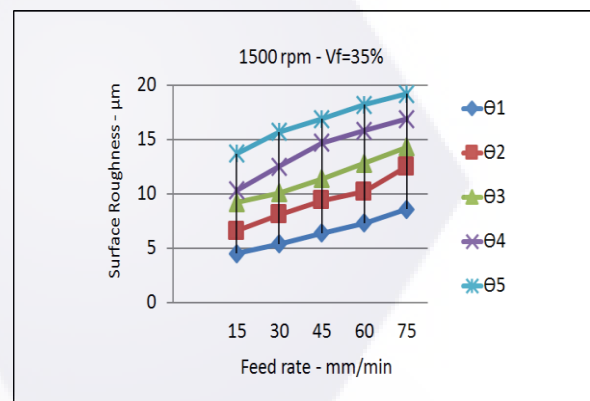

Figure 11: (df - f) Relation at; Vf =35%, RPM 1500 and five tools of different point angles.

Figure 12: (Ra- f) Relation at; Vf =35%, RPM 1500 and five tools of different point angles.

From Figure (12), it can be seen that, the surface roughness (Ra) is increased with the increase of feed rate and increases with the increase of the tool point angle. With feed rate 15 mm/min, the ratios of increase in (Ra) are from; 2.3 % with tool of point angle (70°) to 2.5, 2.8 and 3.2 % for the others used tools. The ratios of increase in (Ra) for feed rates 30, 45, 60 and 75 mm/ min and with tool of point angle (60°) are; 2.9, ; 3.4, 3.8 and to 4.3%. With the tools of (70°, 80°, 90°and 100°) and feed rate 30 mm/min, the ratios of increase are; 2.6 % with tool point angle (70°) to 3.0, 3.8 and 4.4% with the other tools. When used feed rate 45 mm/min, the values is between; 3.0 and 4.5 % for the four used tools. The ratios of increase in (Ra) for the other used feed rates 60 and 75 mm/min are; 3.3 and 3.6 % with tool of (70°) and with tool of (80°) point angle the values are changed to; 3.6 and

3.3. RPM 2500 and Vf 15%
In Figure (13), the relation between feed rate (f) and delamination factor (df) with three parameters is plotted. These parameters are used in the previous experiment, but the cutting speed is changed to 2500 rpm and volume fraction ratio is changed also to 15%. From this figure, the delamination factor (df) is increased with the increase of feed rate and also increases with the increase of the tool point angle. The average increase in (df) is between; 1.01 to 1.11 with the used tools and at feed rate 15 mm/min. For the used feed rates 30, 45, 60 and 75 mm/min, the ratios of increase in (df) are; 0.53, 0.65, 0.75 and 0.81 % with the tool of (60°) and with the tool of (70°) point angle, the ratios of increase are changed to; 0.55, 0.66, 0.78 and 0.85 % and for the tool of point angle (80°), the values are; 0.60, 0.68, 0.77 and 0.87 %. When used the tools of point angles (90 and100°), the

ratios of increase are; 0.69, 0.78, 0.86 and 0.89 % and 0.70, 0.74, 0.84 and 0.92 % with the same feed rates. It is obvious that, the feed rate and the point angle of the tool play a strong role in the resultant values of delamination factor (df) at the used parameters. Also, the change of cutting speed to 2500 rpm with the same used parameters, is led to an increase in the values of delamination factor (df). The change of the cutting speed from 1500 to 2500 rpm when used the same parameters with feed rate 15 mm/min and (VF=15%) leads to an increase in all values of (df). The ratios of increase in (df) are; 1.02 % with tool of point angle (60°) to; 1.03, 1.05, 1.07 and 1.09% for the other four tools (70, 80, 90 and 100°). With feed rate 75 mm/min and the same parameters, the ratios of increase in (df) are; 1.13, 1.15, 1.21, 1.22 and 1.31 for the used tools.

The relation between feed rate (f) and surface roughness (Ra) with three drilling parameters; the cutting speed (2500rpm), the used feed rates, the used tools and with volume, fraction ratio 15% is plotted in Figure (14). The ratios of increase in (Ra) for feed rates 30, 45, 60 and 75 mm/ min and with tool of point angle (60°) are; 2,2, 2.4, 2.6 and to 2.9 % . With feed rate 15 mm/min, the ratios of increase in (Ra) are; 2.3 % with tool of point angle (70°) to 2.5, 2.7 and 3.0 % for the others tools (80, 90 and 100°) respectively. With the tools of (70, 80, 90 and 100°) and feed rate 30 mm/min, the ratios of increase are; 2.4 % with tool point angle (70°) to 2.8, 3.4 and 4.5 % with the other used tools. When used feed rate 45 mm/min, and with the four used tools, the ratios are changed to; 3.2, 3.6, 4.4 and 4.6 %. The ratios of increase in (Ra) for the other used feed rates 60 and 75 mm/min are; 3.4 and 3.7% with tool of (70°) and with tool of (80°) point angle the values are changed to; 3.9 and 4.2 %. When used tools of point angles (90 and 100°), the percentages of increase are; 4.3, and 4.4 % and 4,5and 4.7% for the same feed rates. It is obvious that, the cutting speed plays important role in the resultant values of the surface roughness (Ra), also, the feed rate and point angle of the tool are had a large effect in the resultant values of (Ra) at the used parameters.

The change of the cutting speed from 1500 to 2500 rpm when used the same parameters with feed rate 15 mm/min and (VF=15%) leads to a decrease in all values of the surface roughness (Ra). The ratios of decrease in (Ra) are; 0.55 % with tool of point angle (60°) to; 0.68, 0.78, 0.84, 0.92 % for the other used tools. With feed rate 75 mm/min and the same parameters, the ratios of decrease in (Ra) are; 0.90, 0.91, 0.93, 0.95 and 0.98% for all used tools.
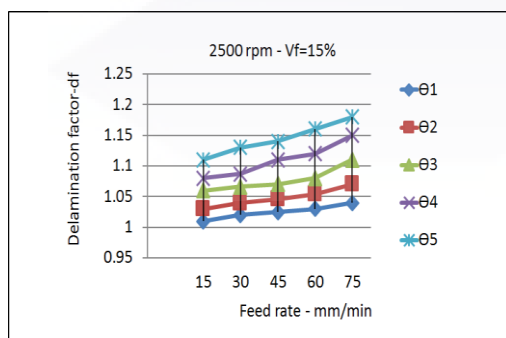

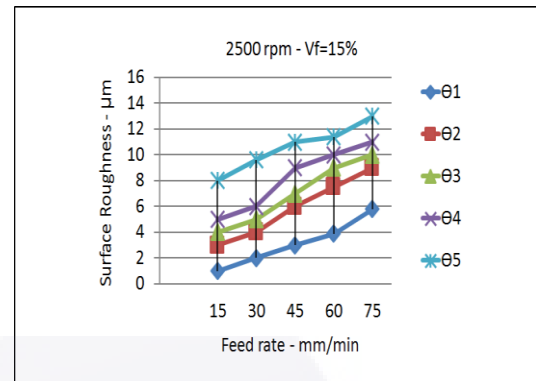Figure 14: (Ra- f) Relation at; Vf =15%, RPM 2500 and five tools of different point angles.

3.3.1. RPM 2500 and Vf 25%

In Fig. (15), the same parameters, which are used in the previous figure, but the volume fraction, is changed from 15 to 25%. The average increase in (df) is between; 1.021 to 1.071 for the used feed rates and with the used tools. For the feed rates; 30, 45, 60 and 75 mm/min, the ratios of increase in (df) are; 0.54, 0.66, 0.76 and 0.82 % with tool of (60°) and the ratios of increase are changed to; 0.57, 0.68, 0.79 and 0.86 % with the tool of (70°) point angle. When used the tools of point angles (90 and100°), the ratios of increase are changed to; 0.72, 0.82, 0.89 and 0.92 % and 0.76, 0.80, 0.86 and 0.94 % with the same feed rates. From these results, the volume fraction, feed rate and the tool point angle are play a vital role in the resultant values of delamination factor (df) at the used parameters. The change of (Vf) from 15 to 25% when used the same parameters with cutting speed 2500 rpm leads to an increase in all values of (df). The ratios of increase in (df) when used feed rate 15 mm/min and with the five used tools are; 1.12, 1.13, 1.18, 1.22 and 1.26 %. Also, with the feed rate of 75mm/min and the five used tools, the ratios of increase in the (df) are; 1.21, 1.24, 1.28, 1.29 and 1.34 % respectively. From the analysis, the delamination factor (df) is increased with the increase of the feed rate and also with the increase of the point angle of the used tools between (VF, 15 and 25%) with the same cutting speed 2500 rpm. In the other side, the comparison between the results when used cutting speed 500 rpm, the five used tools and feed rate 15 mm/min when (Vf)is changed from 15 to 25% with the same parameters when used cutting speed 2500 rpm, the analysis indicated that, the increase in the volume fraction and the cutting speed are led to an increase in the delamination factors(df). The ratios of increase in (df) are; 1.24 % with tool of point angle (60°) to 1.28, 1.32, 1.34 and 1.36 % for the other four tools (70, 80, 90 and 100°). Also, with feed rate 75 mm/min and the same parameters, the ratios of increase in (df) are; 1.25, 1.32, 1.33, 1.36 and 1.42 % for the used tools.

The relation between the feed rate (f) and the surface roughness (Ra) with the same parameters, which are used in the previous figure, is plotted in Fig. (16). The increase in the feed rate leads to an increase in the surface roughness of machined hole, and (Ra) also increased with the increase of tool point angle. The ratios of increase in (Ra) for feed rate 15 mm/min are from; 2.6 % with tool of point angle (70°) to 2.9, 3.6 and 4.1 % for the others tools (80, 90 and 100°) respectively.

Figure 13: (df - f) Relation at; Vf =15%, RPM 2500 and five tools of different point angles.

But with the other feed rates, it is changed to; 2.8, 3.2, 3.6 and to 3.8 % with tool of point angle (60°).When used feed rate 30 mm/min, (Ra) is increased from, 3.6 % with tool point angle (70°) to 4.0, 4.5 and 4.9 % for the other used tools. When used feed rate 45 mm/min, the values of increase are changed to; 3.8, 4.2, 4.7and 5.1 % for the four used tools. For the other used feed rates, 60 and 75 mm/min, the ratios of increase are; 3.9 and 4.5 % with tool of (70°) and 4.1 and 4.9 % with tool of (80°) point angle. When used tools of point angles (90 and 100°), the ratios of increase are; 4.5 and 5.0 % and 4.7and 5.4% for the same feed rates.

It is clear that, the change of volume fraction ratio to 25% with the same used parameters is led to an increase in the values of (Ra). Also, the feed rate and the tool point angle are had a large effect in the resultant values of the surface roughness (Ra) at the used parameters. The change of (Vf) from 15 to 25% leads to an increase in all values of the surface roughness (Ra) when used the same parameters with cutting speed 2500 rpm.

The ratios of increase in (Ra) when used feed rate 15 mm/min and with the used tools are; 1.07, 1.08, 1.09, 1.11 and 1.12 %. With feed rate of 75mm/min and the five used tools, the ratios of increase in (Ra) are changed to; 1.8, 1.09, 1.10, 1.16 and 1.22 % respectively. From the analysis of these results and from this comparison, It is clear that, the values of (Ra) are increased with the increase of the feed rate and also with the increase of the point angle of the used tools between (VF,15 and 25%) with the same cutting speed2500 rpm. In the other side, the comparison between the results when used cutting speed 500 rpm, the five used tools , feed rate 15 mm/min and (Vf = 25%) with the same parameters when used cutting speed 2500 rpm, the analysis indicated that, the increase in cutting speed leads to a decrease in the surface roughness (Ra).

The ratios of decrease in (Ra) are; 0.63 % with tool of point angle (60°) to; 0.66, 0.68, 0.70, 0.74 and 0.78 % for the other used tools. With feed rate 75 mm/min and the same parameters, the ratios of decrease in (Ra) are; 0.87, 0.91, 0.92, 0.96 and 0.97% for all used tools.
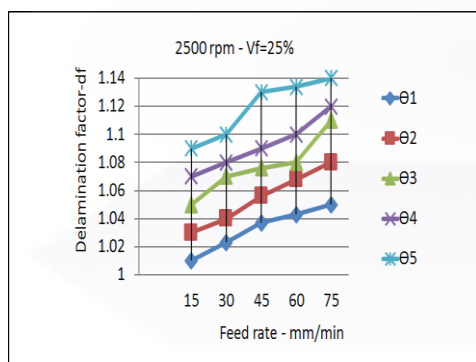

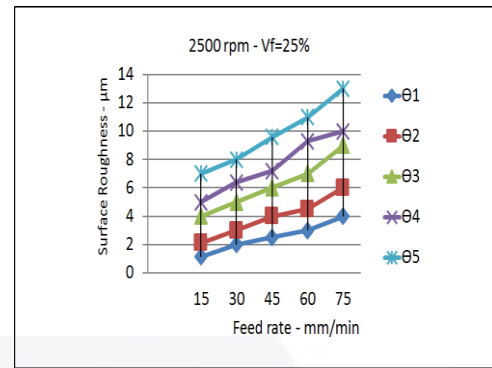Figure 15: (df - f) Relation at; Vf =25%, RPM 2500 and five tools of different point angles.

Figure 16: (Ra- f) Relation at; Vf =25%, RPM 2500 and five tools of different point angles.

3.3.2. RPM 2500 and Vf 35%

In Fig. (17), the same parameters that are used in the previous figure, but the volume fraction is changed from 25 to 35%. The delamination factor (df) is increased with the increase of feed rate and also increases with the increase of tool point angle. The average increase in (df) is between; 1.01 to 1.06 for the used feed rates and with tool of point angle (60°) and is between 1.04 to 1.09 for the other used tools (70, 80, 90 and 100°). For feed rates, 30, 45, 60 and 75mm/min, the ratios of increase in (df) are, 0.56, 0.68, 0.78 and 0.82 % with tool of (60°) and 0.59, 0.70, 0.81 and 0.84 %with tool of (70°) point angle. For the tool of point angle (80°), the ratios of increase in (df) are, 0.61,0.72,0.83 and 0.86 %.When used tools of point angles (90 and 100°), the values are, 0.74, 0.84, 0.86 and 0.88 % and 0.75, 0.82,0.88 and to 0.91 % for the same feed rates. According to the analysis of the experimental results, the feed rate and tool point angle are the highly influential parameter, which influences the resultant values of (df) at the used parameters. From these results also, the volume fraction ratio (Vf) had a large effect on the resultant values of (df) with the same cutting speed. The change of (Vf) from 15 to 35% when used the same parameters with the cutting speed 2500 rpm leads to an increase in all values of the delamination factor. The ratios of increase in (df) when used feed rate 15 mm/min and with the five used tools are, 1.13, 1.18, 1.21, 1.23 and 1.25 %.

Also, with the feed rate of 75mm/min and the five used tools, the ratios of increase in (df) are, 1.17, 1.19, 1.23, 1.25 and to 1.28 % respectively. From the analysis, the delamination factor (df) is increased with the increase of feed rate and also with the increase of point angle of the used tools between (VF, 15 and 35%) with the same cutting speed 2500 rpm. In the other side, the comparison between the results when used the cutting speed 500 rpm, the five used tools , feed rate 15 mm/min and (Vf)is changed to 35% with the same parameters when used cutting speed 2500 rpm, the analysis indicated that, the increase in cutting speed leads to an increase in (df) . The ratios of increase in (df) are; 1.13 % with tool of point angle (60°) to; 1.15, 1.16, 1.17, 1.21% for the other four tools (70, 80, 90 and 100°). With feed rate 75 mm/min and the same parameters, the ratios of increase in (df) are; 1.20, 1.25, 1.27, 1.30 and 1.45 % for the uses tools.

The same parameters, which are used in the previous figure, is plotted in Fig. (18). From this figure, it can be seen that, the surface roughness (Ra) is increased with the increase of feed rate and also increases with the increase of tool point

angle. The ratios of increase in (Ra) for feed rates, 30, 45, 60 and 75 mm/ min and with tool of point angle (60°), are, 3.0, 3.4, 3.8 and to 4.1 %. With feed rate 15 mm/min, (Ra) is increased from, 2.2 % with tool of point angle (70°) to ,2.6, 3.2 and 3.6 % for the others tools (80, 90 and 100°) respectively. With feed rate 30mm/min, (Ra) is increased from; 3.8 % with tool point angle (70°) to 4.2, 5.4 and 5.6 % for the other used tools. When used feed rate 45 mm/min, the values are changed to; 3.9, 4.4, 4.9 and 5.7 %. The ratios of increase in (Ra) for the other used feed rates 60 and 75 mm/min are; 4.0 and 4.4 % with tool of (70°) and with tool of (80°) point angle the values are changed to; 4.3 and 4.6 % . When used tools of point angles (90 and 100°), the ratios of increase are; 4.4 and 5.7 % and 4.5 and 5.9 % for the same feed rates. The change of volume fraction ratio from 25 to 35% with the same used parameters is led to an increase in the values of (Ra). Also, the feed rate and tool point angle are play a vital role in the resultant values of surface roughness (Ra) with the used parameters. The change of (Vf) from 15 to 35% when used the same parameters with the cutting speed 2500 rpm leads to an increase in all values of (Ra). The ratios of increase in (Ra) when used feed rate 15 mm/min and with the used tools are; 1.03, 1.04, 1.07, 1.10 and 1.11 %. With the feed rate of 75mm/min and the five used tools, the ratios of increase in (Ra) are changed to; 1.04, 1.05, 1.09, 1.13 and 1.15% respectively. From the analysis, the values of the surface roughness (Ra) are increased with the increase of feed rate and with the increase of point angle of the used tool between (VF, 15 and 35%) with the same cutting speed2500 rpm. In the other side, the comparison between the results when used cutting speed 500 rpm, the five used tools , feed rate 15 mm/min and (Vf = 35%) with the same parameters when used cutting speed 2500 rpm, the analysis indicated that, the increase in cutting speed leads to a decrease in the surface roughness (Ra). The ratios of decrease in (Ra) are; 0.61% with tool of point angle (60°) to; 0.63, 0.68, 0.70, 0.75 % for the other used tools. With feed rate 75 mm/min and the same parameters, the ratios of decrease in (Ra) are; 0.80, 0.85, 0.92, 0.96 and 0.98% for all used tools.
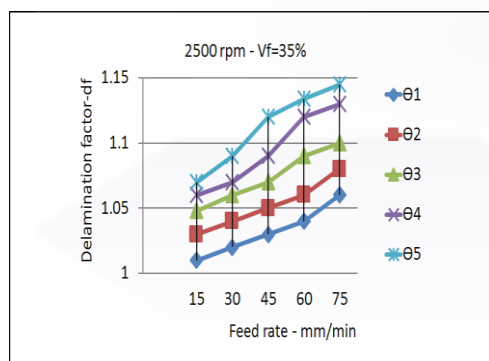

Figure 17: (df - f) Relation at; Vf =35%, RPM 2500 and five tools of different point angles.
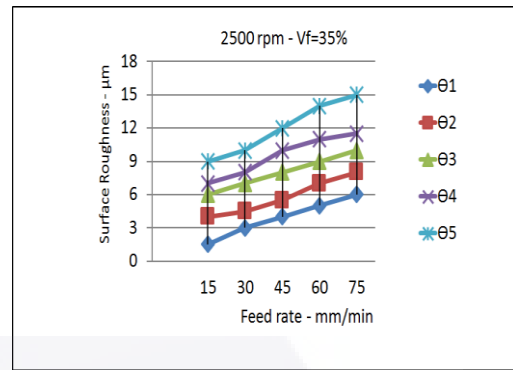

Figure 18: (Ra - f) Relation at; Vf =35%, RPM 2500 and five tools of different point angles.

4. Conclusions

This research presented the experimental methodology which applied to study the influence of drilling parameters; feed rate, tool geometry ,cutting speed, and volume fraction ratio on the process responses, i.e. the delamination (df) and the surface roughness (Ra) of the drilled hole in AL/Sicp metal matrix composite MMC. From the analysis of the results, it can be concluded that:

1) The feed rate and the point angle of the tool are had a large effect on delamination factor (df) and surface roughness (Ra) , while both of the delamination and the surface roughness are increased with the increase in the feed rate from 15 to 75mm/min and the point angle from 60° to 100°.

2) An obvious increase in the values of the delamination factor (df) when the cutting speed is increased to 2500 rpm and feed rate 75 mm/min combined with the tool of point angle (100°).

3) The delamination factor (df) and the surface roughness (Ra) are increased with the increase of volume fraction ratios.

4) The increase of volume fraction ratio is led to an obvious increase in the delamination factor (df) with all values of; the feed rates, the tool of point angles and the cutting speeds.

5) The increase of volume fraction ratio is led to an obvious increase in the surface roughness (Ra) with all values of, the feed rates and the point angle of tools.

6) The analysis of the results demonstrated a strong association between the results of the delamination factor (df) and the surface roughness (Ra) with the point angle of the used tools.

7) The values of the delamination factor (df) are increased with the increase of the tool point angle with all values of, the feed rates, the cutting speeds and volume fraction ratios.

8) The surface roughness (Ra) values are increased with the increase in all values of, feed rates, the tool point angle and the volume fraction ratios.

9) The values of the delamination factor (df) are decreased with the feed rate (15 mm/min), the tool of point angle (60°) and the cutting speed (500 rpm) combined with the volume fraction ratio 15%.

10) The values of the surface roughness (Ra) are decreased with the feed rate (15 mm/min), the tool of point angle (60°) and the cutting speed (2500 rpm) combined with the volume fraction ratio 15%.

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