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Investigation of Surface Roughness and Burr Height of Al/Al_2O_3/Gr Metal Matrix Composite for Various Drilling Parameters

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An Undergraduate thesis submitted to the department of Mechanical & Chemical engineering of Islamic University of Technology, Boar Bazar, Gazipur in partial fulfilment of the requirements for the degree

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(Mechanical and Chemical Engineering)

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CANDIDATES DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Dedicated

To

Our Beloved Parents

CONTENTS

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ABSTRACT

Drilling is a simple and common metal removal process and is important for the final fabrication stage prior to application.This paper discusses the influence of cutting parameters on drilling characteristics of pure Aluminium (Al) plate and Aluminium (Al) metal matrix composites (MMCs) reinforced with 3wt% Graphite(Gr) and 5wt%, 10wt%, 15% Alumina (Al_2O_3). The composites are fabricated using stir casting method. The experiments were conducted to study the effect of spindle speed and feed rate on surface roughness and burr height using high speed steel twist drills of 12 mm diameter having various point angles and lip angles. The results reveal that the alumina- graphite reinforced composites have better surface finish and improved burr heights the than unreinforced sample. Decrement of surface roughness and burr height occur with the increment of the amount of reinforcement. The spindle speed and feed rate extensively affect the surface roughness and burr height of the drilled hole.

CHAPTER 1: INTRODUCTION

In recent years, a significant amount of research took place in quest of new light and high performance engineering materials. Among them, metal matrix composites have earned a substantial place in material engineering due to their extensive properties. Metal matrix composites (MMCs) are a combination of two or more materials, exhibiting properties that are hard to obtain from a single material otherwise. In this combination, one material acts as a matrix and the other acts as reinforcement [1]. The matrix material distributes stress applied over it to the reinforcement constituents which also protects and gives shape to the material. The reinforcement provides the desired mechanical strength to the composite material in a preferential direction. Basically, reinforcements are provided of ceramics that are oxides, carbides and nitrides having excellent combinations of properties like specific strength as well as stiffness at both high and ambient temperature as described by Callister et al. [2]. Metal matrix composites became the important materials in various sophisticated engineering applications like aerospace, marine, automobile and turbine-compressor engineering applications, because of their light-weight, high strength, stiffness and resistance to high temperature [3][4][5]. Among these metal matrix composites, Aluminium alloys reinforced with Al_2O_3 or SiC has been the subject of a considerable amount of research work. The application of Al_2O_3 or SiC reinforced aluminium alloy matrix composites in the automotive and aircraft industries is gradually increasing for pistons, cylinder heads, etc., where the tribological properties of the material are very important [6][7]. They exhibit greater strength, improved stiffness, reduced density(weight), improved high temperature properties, controlled thermal expansion coefficient, thermal/heat management, enhanced and tailored electrical performance, improved abrasion and wear resistance, control of mass (especially in reciprocating applications), improved damping capabilities [8]. Hence, the aluminium metal matrix composites reinforced with Al_2O_3 or SiC are being gained significant emphasis for satisfying the increasing requirement of various industries.

The hard-ceramic materials (Al_2O_3, SiC) in the Al mmc always make them so difficult to machine. Machining of them gives excessive tool wear, poor surface finish by increasing the surface roughness of the composite. Among all machining operations, Drilling is one of the main and common operation. Practically, it is difficult to acquire a hole with good surface finish in Al mmc. But whatever applications have been told earlier, a good surface finished holes are needed at those applications. Basically, in drilling operations, surface roughness determines the economics of machining and rate of production. So, minimizing this surface roughness for getting a better surface finishing is too much anticipated. Moreover, the drilling operation produces burr on inlet and exit surface. The burr is the material extending off the surface of the workpiece.Burr formation affects workpiece accuracy and quality in several ways: dimensional distortion on part edge, challenges to assembly and handling caused by burrs in sensitive locations on the workpiece, and damage done to the work subsurface from the deformation associated with burr formation [9]. In a nutshell, the burrs at the hole edges cut of the performance in precision part and affect the reliability of the assembled product. That’s why an optimum drilling conditions are needed to be explored for minimizing the surface roughness and burr height which are really unavoidable in practice for getting a good economic machining along with a good performance in assembled product.

CHAPTER 2: LITERATURE REVIEW

2.1 Contribution of Alumina (Al_2O_3)reinforcement in Aluminium (Al) matrix:

Aluminium alloys are preferred engineering material for automobile, aerospace and mineral processing industries for various high performing components that are being used for varieties of applications owing to their lower weight, excellent thermal conductivity properties. Aluminium (Al) based metal matrix composites (Al-MMCs) are outstanding candidates for these applications owing to the high ductility of the matrix and the high strength of the hard-reinforcing phases. The attraction for such materials is also due to the very high specific modulus, strength to weight ratio, fatigue strength and wear resistance as reported by JR Stephens [10], Taya et al. [11], DL McDanel [12], DJ Lloyd [13]. The addition of Al_2O_3 to the Al-matrix increases the mechanical properties of the of the matrix alloy. Veeresh et al. [14] performed micro-hardness test of cast Al6061 and Al7075 base matrix and their composites containing 2-6 wt. % age Al_2O_3 are evaluated using diamond indenter at an applied load of 100N. They concluded that the composites containing higher filler contents exhibit higher hardness. Further, they observed that the hardness of the Al7075-Al_2O_3 composite are higher than that of the composite of Al6061-SiC. And also, as explained by Wu et al. (2000), the matrix Al7075 and Al_2O_3 possess higher hardness. Veeresh et al. [14] demonstrated that the tensile strength of the Al matrix also increases due to addition of the Al_2O_3 as reinforcement. M. Kok [15] investigated the experimental density of Al/Al_2O_3 composites by the Archimedean method of weighing small pieces cut from the composite cylinder first in air and then in water, while the theoretical density was calculated using the mixture rule according to the weight fraction of the Al_2O_3 particles and he concluded that the density of the composites increases with increasing weight percentage and size of particles. He also explained the tensile strength and hardness of Al/Al_2O_3 MMCs increases but the elongation of them decreases, with decreasing size and increasing weight percentage of the particles. Aghajanian et al. [16] determined the elastic properties, tensile properties, compressive properties, and fracture characteristics of the Al/Al_2O_3 metal matrix composites. They revealed that increases in reinforcement content resulted in systematic increases in Young's modulus and at high loading, the composites can get the stiffness of over 2.5 times that of the base alloy. Also, as explained by Aghjanian et al. [16] the tensile yield (0.2% offset) and ultimate strengths increase with reinforcement content, and the rate of increase in strength is highest in the more highly loaded composites. In that experiment, the strongest composite possessed tensile yield and ultimate strengths 2.8 and 2 times greater, respectively, than those of the unrein- forced base alloy.

Reinforcement of aluminium alloys with particles has been generally observed to improve wear and abrasion resistance under abrasive wear and under lubricated sliding wear conditions. For example, Bansali et al. [17] and Wang et al. [18] investigated the improvement of wear resistance under abrasive wear condition where Prasad et al. [19] and Pan et al. [20] did the wear resistance experiment under lubricated sliding wear condition. However, conflicting reports exist in the literature regarding the role of carbide and oxide particles in improving the wear behaviour of Aluminium (Al) composites. This is due to the fact that sliding velocity, load level, particle size as well as concentration together with type of counter-face and lubricating condition pose a complex combination of conditions that affect the wear behaviour. Surappa et al. [21] reported that the addition of 5% Al_2O_3 particles

(20 µm average size) does not significantly improve the wear resistance of hypereutectic Al–Si alloys. The degree of improvement of wear resistance depends mainly on the nature of the reinforcement and the manufacturing technique of the composite, which in turn determine the properties and nature of the interface between the reinforcement and the matrix. Effect of adding 10% of sub-micron size particles of Al_2O_3 into 6061 aluminium alloy on wear behaviour has been investigated by Al-Qutub et al. [22]. The primary conclusion of this investigation was a significant improvement of dry wear resistance with the 10 % addition of Al_2O_3 sub-micron particles. Al-Qutub et al. [23] proved in another experiment that the addition of 10% alumina to the matrix alloy improves the wear resistance by 20–106% depending on the applied load. For the 20% alumina composite the improvement in wear resistance falls between 35 and 257%. Further increase of alumina concentration to 30% in the matrix alloy improves wear resistance between 37 and 314%. SEM results of this study also illustrate three clear types of wear namely, abrasion, delamination and adhesion. Low loads resulted in abrasion dominant wear. Higher loads resulted in delamination dominant wear with some adhesion at extreme loads. Normalized wear rate (composite wear rate / matrix wear rate) decreases with the increase of reinforcement volume fraction, and limit after which this becomes apparent is about 20 % as explained by Prasad et al. [24], Sannino et al. [25], Venkataraman et al. [26]. The analysis of wear factor also supports these experiments' results. The wear factor decreases with the amount of Al_2O_3 reinforcement [14].

Corrosion behaviour is associated closely with the presence of heterogeneities, and MMCs have a large quantity of heterogeneities in the form of reinforcement, microcrevices, voids, porosity, second-phase precipitates, and interaction products. The introduction of the reinforcement into the matrix alloy gave rise to two kinds of corrosion problems as investigated by Nunes et al. [27]. The first was associated with galvanic effects. In the Al/Al_2O_3 composites, galvanic coupling exists to a reduced extent between the precipitated second phases and the matrix. The second problem involved the formation of microcrevices at the interfaces and voids. Certain interfacial defects arose from incomplete cohesion between reinforcement and matrix. At these defects, the local chemistry necessary to retard local repassivation was achieved early and crevices or trenches formed. It's depicted from this experiment that increases in corrosion resistance of the composites from anodization or immersion in $CeCl_2$solutions can be attributed to the formation of a defect-free surface film.

2.2 Contribution of Graphite (Gr) reinforcement in Al matrix:

It is well recognized that when a soft metal like Aluminium (Al) slides on hard steel without any external fluid or solid lubrication, the former is expected to flow and adhere to the latter, creating an interface of low shear strength. Transfer of Aluminium (Al) will continue with sliding, and wear debris may form as a result of ploughing of the soft Aluminium surface by the asperities of the hard steel, or flaking off of patches from the transfer film as clarified by A.D. Sarkar [28]. Prasad et al. [29] explored that friction coefficient between aluminium and steel couples is high ~ 0.5–0.6. The development of Aluminium MMCs dispersed with solid lubricants is primarily directed towards overcoming the principal drawbacks of aluminium as a tribological material.

Rohatgi and coworkers [30-34] first introduced Graphite (Gr) as a solid lubricant in aluminium matrices by casting routes, involving mixing the molten alloy with graphite particles to make a uniform suspension and followed by casting. This "solid lubricant" concept is also stated asserted by Ames et al. [35]. Ames et al. explained this fact specially for the case of drilling operation. The wear has been significantly influenced by the formation of a thin lubricating film of Gr particulates and removal of worn material was noticed consequent to the failure of this film as described by Liu et al. [36]. Lin et al. [37] have investigated Al–Gr composites with 0–6 wt% Gr and the results indicate reduced wear rate with increase in particulate content. Decrease of wear has been attributed to prevention of direct contact of sliding surfaces and reduced ploughing effect of Al chips due to the quick formation of lubricating film of graphite particulates.

Basically, the fabrication of composites containing so-called ‘‘soft particles’’ (graphite or copper) favours a reduction in the coefficient of friction as elucidated by Rohatgi et al. [38]. Thus, Yılmaz et al. [39] proved that the wear rate of Al/Al_2O_3 decreases due to the increment of the Graphite (Gr) amount. Songmene and Balazinzki [40] and Basavarajappa et al. [41] reported the effect of graphite in Al/SiCp–Gr composites. According to them, inclusion of graphite in the composite has reduced the hardness and strength of the composite. These are favourable for machinability. The investigation on machining of Al–Gr composites by Krisnamurthy et al. [42] has indicated considerable reduction of cutting forces and this has been attributed to the possible reduction of friction due to solid lubrication of Gr particulates. Hocheng et al. [43] and Chu et al. [44] concluded that the temperature rise at the wearing contact surface reduces due to the addition of Graphite (Gr).

From the above discussion, we can understand that the addition of Al_2O_3 in the Al matrix increases the mechanical and tribological properties. But the increment of hardness of the Al-matrix results in rise of tool wear and poor surface finish. And also, using graphite as a lubricant material causes loss in strength of the whole composite. But when they aggregate as a metal matrix composite, it becomes a tremendous material for use in a sophisticated application field. Because, Al/Al_2O_3/Gr are self-lubricating materials containing graphite lubricant, and yet their strength is enhanced by the presence of the Al_2O_3 ceramic phase.

2.3 Effect of Machining Parameters on the Surface Roughness of Aluminium(Al) based MMC

In recent years, the particulate reinforced Al metal matrix composites are replacing the conventional materials that are used in aircraft and automotive components. The most common applications are aircraft's engine cowlings, landing gear doors, automotive pistons, bearings, etc. In those major applications, the manufactured components are expected to be with good surface finish and accuracy. Ciftci et al. [45] explained particulate reinforced Aluminium (Al) based composite are found very difficult in machining due to the presence of hard ceramic oxide reinforcement. The hard-ceramic particles like Al_2O_3/SiC present in the matrix makes it difficult to machine which in turn reduces the surface finish by increasing the surface roughness of the composite. In such cases, the addition of graphite to the matrices reduces the tool wear while machining and improves the surface finish of the composite as described by Seeman et al. [46].Most of the studies on Metal matrix composite (MMC) are focused on the study of tool wear characteristics during machining of aluminium alloy composite. The surface finish of the component can be varied along the process parameters such as spindle speed, feed etc. From the various literatures, it has been observed that feed rate, cutting speed and wt % of the reinforcements are key factors influencing surface roughness. Palanikumar and Karthikeyan [47] made an attempt on assessing the factors influencing surface roughness on machining of Al/SiC particulate composite. They have used K10 tungsten carbide tool inserts for machining. The machining parameters considered were % vol fraction of SiC, cutting speed, depth of cut and feed rate. They employed ANOVA technique to optimize the machining parameters. Saravanakumar and Sasikumar [48] made a study on prediction of surface roughness in turning using design of experiments. They concluded that selection of reinforcements plays an important role in improving the material properties and machinability of the composite. Considering two levels of factors, they had developed a mathematical model for the proposed cutting parameters. Paulo davim and Conceicao Antonio [49] aimed at the selection of optimized values for the cutting conditions while drilling and turning. It was found that feed rate is the most constituent factor which affects surface finish rather than the cutting speed. Basavarajappa et al. [50] focused on drilling characteristics of Al2219/15SiCp and Al2219/15SiCp–3Gr hybrid composite. They have used solid carbide multifaceted drills of 5mm diameter at various cutting conditions. They studied the effect of spindle speed, feed rate on surface finish. The results reveal that ceramic-graphite reinforced composite shows better machinability since graphite acts as a solid lubricant and reduces material wear. Sivasankaran et al. [51] conducted turning experiment and studied the effect of graphite addition to Al 7075 alloy and proved that the presence of graphite particles in the matrix reduces the surface roughness during machining. Due to the self-lubricating property of the graphite particles during machining, it improves the machinability and surface finish. Saravanakumar et al. [52] in their study concluded that addition of Al_2O_3 more than 6%wt to the matrix leads to the clustering and agglomerations resulting in poor distribution of the reinforcements. Metinkok [53] presents an experimental investigation on the effect of surface roughness factors in the machining of Al2024/ Al_2O_3 particulate composite. The test results revealed that surface roughness increases with increasing cutting speed and decreases with the increased size and volume fraction of the particles. Jeyaraman and Maheshkumar [54] have used grey relational analysis and taguchi method for optimizing the machining parameters in turning AA6063 T6 aluminium alloy.

The experimental outcomes showed that the best multiple performance characteristics was obtained with the lower cutting speed, lower feed rate and medium depth of cut in turning AA. Venkatesan et al. [55] made an attempt on optimizing the machining parameters using Response Surface Methodology in machining of AA hybrid composite. They have used Al 356 hybrid matrix by varying weight fraction of SiC (5%, 10% & 15%) and keeping boron carbide as (5%) constant. The Response Surface Methodology results confirm that the surface roughness criteria increase with increase of feed and decreases at higher cutting speed. Juan Carlos Campos Rubio et al. [56] performed an investigation on drilling of reinforced and unreinforced polyamides using Taguchi analysis in order to identify the best drilling setup of glass reinforced polyamides. The conclusions revealed that the quality of the drilled holes can be improved by proper selection of cutting parameters.ElGallab and Sklad [57] studied tool performance and work piece integrity of machining of Al/SiC PMMCs. Surface roughness measurement show that the surface roughness improves with an increase in the feed rate and cutting speed, but slightly deteriorates with an increase in the depth of cut. This was attributed to the reduction in the flank wear of the tool with an increase in the feed rate.Zhang and Cheng [58] studied to efficiently determine the optimal drilling parameters to achieve the smallest surface roughness value for 1018 low carbon steel plates under varying conditions and they optimized the surface quality in a CNC drilling operation by Taguchi design.Brown and Surappa [59] studied the machinability of Al–Si–graphitic particle composite and they are under the opinion that the reduction in machining forces with graphite reinforcement content is due mostly to a decrease in the shear flow stress rather than to lower chip-rake-face friction. The results indicate that machined surfaces of Al–Si alloy–graphite composites tend to be rougher than similar surfaces on similar material without graphite because of deeper holes or valleys. Konig and Grass [60] studied the surface texture of holes and analyzed the drilling of fiber reinforced thermosets (carbon fiber, glass fiber, aramid fiber) by quantifying the amount of machining damage using ten-point height and width of the damage zone. Darwish et al. [61] investigated the effect of the cutting parameters and tool wear to the work piece surface roughness produced, which could be misleading. This is because in most cases during the machining of Al/ SiCp MMCs the surface roughness produced, the surface roughness is much lower than that obtained during the machining of the matrix alloy alone.Monaghan and O'Reily[62] attributed the improved surface finish to the burnishing or honing effect produced by the action of small SiC particles trapped between the flank face of tool and the work piece surface.Monaghan and O'Reily [63] used coated and uncoated high speed steel, carbide and PCD tipped drills and solid carbide drills in the drilling tests. The results indicate that the hardness of the tool material has a significant influence on cutting edge wear and on the drilling torque, surface finish, and thrust forces. drilling torque, surface finish, and thrust forces. Oden and Ericsson [64] studied the near surface deformation in an alumina–silicon carbide whisker composite due to grinding. Davim [65] studied the drilling of metal matrix composites based on Taguchi technique to find the influence of cutting parameters on tool wear, torque, and surface finish and the interactions between the above factors. He analyzed the data by analysis of variance and found the percentage of influence of each factor on responses. In addition, he presented a study of the influence of cutting parameters and cutting time on drilling MMCs based on the techniques of Taguchi. Tosun and Muratoglu [66], dealt with the surface integrity of drilled Al/SiCp MMCs. Dry drilling tests at different drilling conditions have been conducted in order to investigate the effect of the various cutting parameters on the surface quality and the extent of the deformation of drilled surface due to drilling. Tosun and Ozler [67] investigated the possibility of application of statistical approaches to see the level of importance of machining parameters on surface roughness and tool life in hot turning operations. Recently an attempt has been made by Saravanakumar et al. [68] to optimize the machining parameters for better surface roughness in drilling of Al 6063/Al_2O_3/Gr particulate composite. He concluded that the surface roughness of the drilled hole decreases at increased speed and decreased feed rate. From the response table for S/N ratio, it is confirmed that feed rate is the most influencing factor followed by wt % of alumina and spindle speed in reducing surface roughness during machining of Al/Al_2O_3/Gr composite. The optimal parametric conditions obtained for minimizing surface roughness are at highest spindle speed of 3000 rpm, lowest feed rate 50 mm/min, 6wt % of Al_2O_3.

2.4 Effect of Machining Parameters on the Burr Height of Aluminium (Al) based MMC

Burr is plastically deformed material generated on both the entry and exit of the hole. These burrs cause several problems for product quality and functionality as they can interface with assembly of parts and can cause jamming effect. The formation of burrs at the end of a cut is similar to the formation of chips. Basavarajappa et al. [69] published that the significant factor for feed rate on burr formation is 79.49% for Al2219/15SiCp and is 63.17% for Al2219/15SiCp-3Gr. The burr formation when drilling Al2219/15SiCp-3Gr is less than that of Al2219/15SiCp. The incorporation of graphite in SiCp reinforced composites helps the material to shear easily and formation of discontinuous chip during the drilling of thecomposite. Barnes et al. [70] showed that softer as-extruded and solution-treated materials produced less wear and lower cutting forces than the harder-aged materials. However, the height of the burrs produced during drilling was found to be greater than the softer materials and the quality of the drilled surface was also inferior. Jadoun et al. [71] discussed the influence of cutting parameters on drilling characteristics of a hybrid metal matrix composites. The composites are fabricated using stir casting method. The Taguchi design of experiments and ANOVA are employed to analyze the drilling characteristics of these composites. Their study applied cutting velocity and feed rate as experiment factors and used feed force, surface finish, and burr height as evaluation criteria. The study found that the evaluation criteria were greatly impacted by feed rather than by speed. Rajmohan et al. [72] used solid carbide tool for the study of minimization of burr height in drilling of Al356/SiC/Mica hybrid composites and found that feed rate is the most influencing factor followed by spindle speed. Saravanakumar et al. [73]analyzed the burr height of the AA 6063-6 wt-% Al_2O_3-x wt-% Gr (x = 0 and 1 wt-%) composites which was produced by stir casting method and concluded that the burr height decreases with increase in Spindle speed but increases with increase in feed rate for both the composites. The graphitic composite shows less burr height than Al2O3p reinforced composite. Gaintonde et al. [74] have studied minimizing the burr height and burr size in drilling of AISI stainless steel. They employed PSO approach to select the best combination of process parameters to minimize burr height and burr size. T.Rajmohan et al. [75] used fuzzy logic algorithm to optimize the machining parameters in drilling of hybrid metal matrix composites. They conducted 27 different experiments according to Taguchi's orthogonal array. They identified that at higher cutting speed, burr height slightly decreases, with the effect of grey relational coefficient of responses and grey fuzzy reasoning grade. Shanmughasundaramand Ramanathan Subramanian [76] investigated for burr minimization in drilling of Al–Gr composites which are fabricated through squeeze casting method. The results revealed that feed rate is the most significant parameter followed by step angle, step size and spindle speed in the exit burr height. Pande and Relekar [77] have analyzed burr formation in terms of burr height and thickness by varying the cutting speed and feed rate. Sung-Lim Ko and Jing- Koo Lee [78] have studied the influences of cutting conditions like cutting velocity, feed rate and drill's geometries on accuracy of hole and burr formation. NihatTosun [79] reported the use of grey relational analysis for optimizing the drilling process parameters for the surface roughness and burr height. Lin [80] investigated the tool life, surface roughness and burr formation in high-speed drilling of stainless steel using TiN-coated carbide drill.

From the literature review of effect of various machining parameters on the surface roughness and burr height, a fact can be extracted that a large number of studies have been accomplished in this field specially in the case of SiC reinforced Al mmc. But there is a lack of experiments in the case of Al_2O_3 reinforced Al mmc specially evaluation of surface roughness and burr height using drill bits having various point angles and lip angles. In some researches, it has been proved that SiC reinforced Al mmc is superior than Al_2O_3 reinforced composites (Veeresh et al.2010). But, for the low-cost application Al_2O_3 reinforced Al mmc is more recommended than the SiC reinforced Al mmc. So, investigation of optimum drilling parameters in the case of Al/ Al_2O_3/Gr using drill bits having various point angles and lip angles need to be accomplished.

CHAPTER 3: EXPERIMENTAL

3.1 Fabrication of the Samples:

For this experiment, Al-Al_2O_3- Gr metal matrix composites are used. Al_2O_3 particle are added to increase the strength and graphite particles addition improves machinability [51].The other major problem is its lower wettability below 900 K [81].Here alumina provides wettability. In this experiment Al_2O_3 is taken in various percentage as 5 %, 10%, 15% and Gr is fixed as 3% of weight fraction (Table 1).Alumina (Al_2O_3) and graphite (Gr) particles of average particle size (APS) 53 and 23 mm, respectively, are used for casting of Al-MMCs. Alumina increases tensile strength, yield strength, toughness, density, micro-hardness and decreases wear factor (at lower RPM) whereas Gr acts as solid lubricants.

3.1.1 Casting procedure:

The composites have been fabricated using stir casting technique at an optimal speed to ensure even distribution of the reinforcements along the matrix. M. Kok [15] recommended an optimal condition for Al/Al_2O_3 fabrication. Those optimal conditions are as follows: pouring temperature: 700◦C, pre-heated mold temperature: 550◦C, stirring speed: 900 rev min−1, stirring time: 5 min after the completion of particle feeding, particle addition rate: 5 g min−1and applied pressure: 6 MPa. But, a simplestir casting method is implied to avoid complexity. Thus, the results will be little bit deviated from the proper desired results.

The samples are taken to the size of 12” *4” *0.6” (Figure 1).The melting was carried out in a clay–graphite crucible placed inside the furnace (Figure 2). Aluminium was first preheated at 700K for 2 h before melting and Al_2O_3 particulates were preheated at 1100K for 1 h to improve the wetting properties by removing the absorbed hydroxide and other gases. The furnace temperature was first raised above the liquidous temperature, i.e.750K to melt the matrix completely and then cooled it down [82]. After adding all reinforced particles, the crucible is kept inside the furnace. The molten metal is stirred at speed of 200 rpm for 5 minutes. At the same time, dies are preheated at 300^oC in another muffle furnace for 2 hour. Finally, the molten metal poured into the preheated die and then the metal is allowed to solidify.

The mold was taken to a hydraulic press and subsequently 6 MPa pressure was applied to the mixture in order to reduce the porosity inthe composites and improve the bonding force between the Al alloy/Al_2O_3 particles. The time of applied pressure was about 30 s. Finally, the mold was opened after 5 min and the fabricated billets were air-cooled to room temperature. Unreinforced matrix alloy bars were also produced by the same method.

3.2 Machining

3.2.1 Shaping

After completing metal casting job pieces are well shaped by shaping machine.The samples are made 12” *4” *0.6” in size (Figure 1).

3.2.2 Drilling

In this stage, drilling operations are done by CNC drilling machine; various feed rate and cutting speed taken while drilling but mostly cutting speed does not have an influence on cutting forces while machining of MMCs, according to Coelho [26].During drilling, different drill bits are used different lip angle(9,10,11) and point angle(122,130,126etc) along with varying spindle speed (Table 2-4).

3.3 Measurement

3.3.1 Surface Roughness

Average surface roughness is measured with various combination of spindle speed, feed rate and with different drill bits having different lip angle and point angle.

Mitutoyo Roughness machine is used in this measurement (Figure 3). Roughness measurement machine was suspended on a height gauge (Figure 4).Job piece was placed at a vertical distance from the base for better measurement by using a vice (Figure 4).At the beginning of each measurements, the needle of the machine was made concentric with the corresponding drilled hole at the entrance. Then the machine was calibrating itself and indicates the blue signal.As the machine shows blue signal immediately start button was pressed. On that moment needle was moved forward and backward and thus roughness is measured. Finally,Mitutoyo roughness machine gives the roughness value.

3.3.2 Burr Height

Image J 1.50i is used for burr height measurement purpose. It is a java image processing program (Figure 5).

(Figure 6-10) Burr height is measured from images with respect to a reference scale by using the software. For the purpose of a scale, a coin having 1.35 mm is kept beside the holes during taking pictures.Then plugged in the images in the software. A line having an angle 90 degree along the thickness of the coin. In the software select analyze and select set scale and known distance is 1.35mm coin thickness. So, that pixel aspect ratio of the line become fixed. Thus, length of every lines drawn can be measured w.r.t this standard scale. Burr height is measured from four different position on the drill hole; like 0, 90, 180 and 270 degree positions. Finally make an average of these.

CHAPTER 4: RESULT AND DISCUSSION

4.1 Surface Roughness

From the graph (Figure 11), it is clear that surface roughness curve is clearly decreased as the percent of Al_2O_3 increased. From different points, it can be identified that roughness decreases at the corresponding point which is totally identical to our earlier literature reviews;

(i)At point 12 values are 11.65,10.75,9.28,6.8 (μm) and at point 13 values are 7.615,7.525,7.14,4.955(μm).It is clear from graph and table that increasing percent of Al_2O_3 minimizes roughness.

(ii) At different point roughness is varied due to different Lip angle and point angle combination. At point 06,13,18,19,23 lower roughness values are measured.

(iii)Point 19 carries 2.1588 is the lowest roughness value at plate 04 having configuration of spindle Speed 1000 (rpm), Feed 200 (mm/min), Point Angle 126 (Degree),Lip Angle 10 (Degree).

(iv)Due to lack of available resources and modern technology machine data may be deviated from actual values.

4.2 Burr Heights

(i)burr height also decreases with increased percent of Al_2O_3.from graph plate 01 has highest values of burr where plate 4 has lower values of burr height (Figure 12).

(ii)At point 6,13,17,18,19,24 having lower values.Among them point 13 and 17 carries lowest value of burr height.

Point 18 have common lower value for both roughness and burr height it' parameters are Spindle Speed 1200 (rpm), Feed 360(mm/min),Point Angle 126(Degree),Lip Angle 10(Degree).

CHAPTER 5: CONCLUSION

(i)As the as the percent of Al2O3 increased and addition of constant 3% Gr shows surface roughness curve is clearly decreased.

(ii)Burr height also decreases with increased percent of Al2O3 addition of constant 3% Gr.

(iii)We couldn’t accomplished our target completely. We hoped that the curves we obtained should be linear or exponential or in other significant form through which some equations or empirical relations could be extracted.

Due to lack of proper fabrication condition, reinforcement is not uniformly distributed. We didn’t have any automatic stirrer or haven’t any scope to attach a stirrer with the furnace. By attaching a hand-made stirrer with a drill machine, the mixing of the reinforcements was done. So, we couldn’t meet the optimal stirring time 5-10 min. To achieve proper mixing, we have to measure the temperature of material at different stages. But we couldn’t do that properly.

Moreover, there was a lack of practical expertise about the fabrication of MMC. That’s why proper composites having uniformly distributed reinforcements couldn’t be acquired.

CHAPTER 6: TABLES

Table 1: Specimens and their compositions

Specimen	compositions (%wt)
Plate 1	Aluminium (100%)
Plate 2	3% Gr + 5% Al_2O_3 + Aluminium (rest)
Plate 3	3% Gr + 10% Al_2O_3 + Aluminium (rest)
Plate 4	3 % Gr + 15% Al_2O_3 +Aluminium (rest)

Table 2: Specification of Drill bits

No. of Drill bits	Point angle (Degree)	Lip angle (Degree)
Drill bit 1	122	9
Drill bit 2	130	9
Drill bit 3	122	11
Drill bit 4	130	11
Drill bit 6	126	10
Drill bit 6	118	10
Drill bit 7	134	10
Drill bit 8	126	8
Drill bit 9	126	12
Drill bit 10	126	10

Table 3: Surface roughness analysis

Obs.	Spindle Speed (rpm)	Feed (mm/rev)	Feed (mm/min)	Point Angle (Degree)	Lip Angle (Degree)	Roughness (µm)			
						Plate 01	**Plate 02**	**Plate03**	**Plate04**
1	900	0.25	225	122	9	6.6	6.8	7.05	5.24
2	1100	0.25	275	122	9	4.7	4.88	6.32	5.03
3	900	0.35	315	122	9	5.3	6.81	8.1	6.34
4	1100	0.35	385	122	9	7.2	7.1	7.46	6.76
5	900	0.25	225	130	9	7.0985	7.097	7.38	5.275
6	1100	0.25	275	130	9	5.145	5.11	8.59	3.75
7	900	0.35	315	130	9	6.056	9.955	10.165	6.95
8	1100	0.35	385	130	9	8.5115	7.625	8.0835	6.755
9	900	0.25	225	122	11	5.1895	7.14	10.01	6.42
10	1100	0.25	275	122	11	6.4135	8.755	7.8	7.265
11	900	0.35	315	122	11	6.686	7.005	8.245	6.17
12	1100	0.35	385	122	11	6.8	10.75	11.65	9.28
13	900	0.25	225	130	11	4.4725	5.27	8.085	6.605
14	1100	0.25	275	130	11	4.68	5.965	9.235	5.46
15	900	0.35	315	130	11	5.0235	5.095	5.83	7.145
16	1100	0.35	385	130	11	7.82	5.485	9.29	6.02
17	800	0.3	240	126	10	5.8175	8.9	8.8875	7.15
18	1200	0.3	360	126	10	5.1735	7.75	6.01	7.67
19	1000	0.2	200	126	10	2.1588	6.815	6.75	8.235
20	1000	0.4	400	126	10	4.955	7.525	7.615	7.14
21	1000	0.3	300	118	10	5.194	5.95	7.8	6.46
22	1000	0.3	300	134	10	3.2705	9.095	7.21	6.0915
23	1000	0.3	300	126	8	7.39	10.65	8.165	9.675
24	1000	0.3	300	126	12	3.945	9.55	10.935	7.97
25	1000	0.3	300	126	10	5.024	6.475	11.195	7.48

Table 4: Burr Height analysis

Obs.	Spindle Speed (rpm)	Feed (mm/rev)	Feed (mm/min)	Point Angle (Deg)	Lip Angle (Deg)	Burr height(mm)			
						Plate 01	**Plate 02**	**Plate03**	**Plate04**
1	900	0.25	225	122	9	0.47858	0.84118	0.54625	0.65252
2	1100	0.25	275	122	9	0.56253	0.59512	0.78892	0.66229
3	900	0.35	315	122	9	0.72639	0.5772	0.63342	0.74243
4	1100	0.35	385	122	9	0.69542	0.5132	0.35825	0.59384
5	900	0.25	225	130	9	0.529625	0.665375	0.49925	0.396813
6	1100	0.25	275	130	9	0.484938	0.710688	0.49	0.559938
7	900	0.35	315	130	9	0.415494	0.641875	0.515625	0.599588
8	1100	0.35	385	130	9	0.495563	0.922938	0.458125	0.499
9	900	0.25	225	122	11	0.428375	0.79625	0.597	0.5297
10	1100	0.25	275	122	11	0.663875	0.693063	0.7901875	0.57225
11	900	0.35	315	122	11	0.826188	0.63075	0.77475	0.679219
12	1100	0.35	385	122	11	0.776938	0.500938	0.514875	0.4595
13	900	0.25	225	130	11	0.479188	0.629625	0.549	0.25275
14	1100	0.25	275	130	11	0.598438	0.839044	0.4923125	0.468188
15	900	0.35	315	130	11	0.514625	0.70125	0.6595	0.522688
16	1100	0.35	385	130	11	0.578563	0.916563	0.7008125	0.327438
17	800	0.3	240	126	10	0.33325	0.36025	0.397625	0.179938
18	1200	0.3	360	126	10	0.208688	n/a	0.473875	0.295438
19	1000	0.2	200	126	10	0.163188	0.361188	0.3181875	0.281625
20	1000	0.4	400	126	10	0.264063	0.505438	0.3963125	0.493833
21	1000	0.3	300	118	10	0.239813	0.255813	0.2465625	0.313063
22	1000	0.3	300	134	10	0.338688	0.31655	0.3325625	0.314188
23	1000	0.3	300	126	8	0.378375	0.534875	0.5395	0.408625
24	1000	0.3	300	126	12	0.429125	0.506063	0.333875	0.573563
25	1000	0.3	300	126	10	0.309563	0.344063	0.49415625	0.140125

CHAPTER 7: FIGURES

Figure 1: Four sample specimens

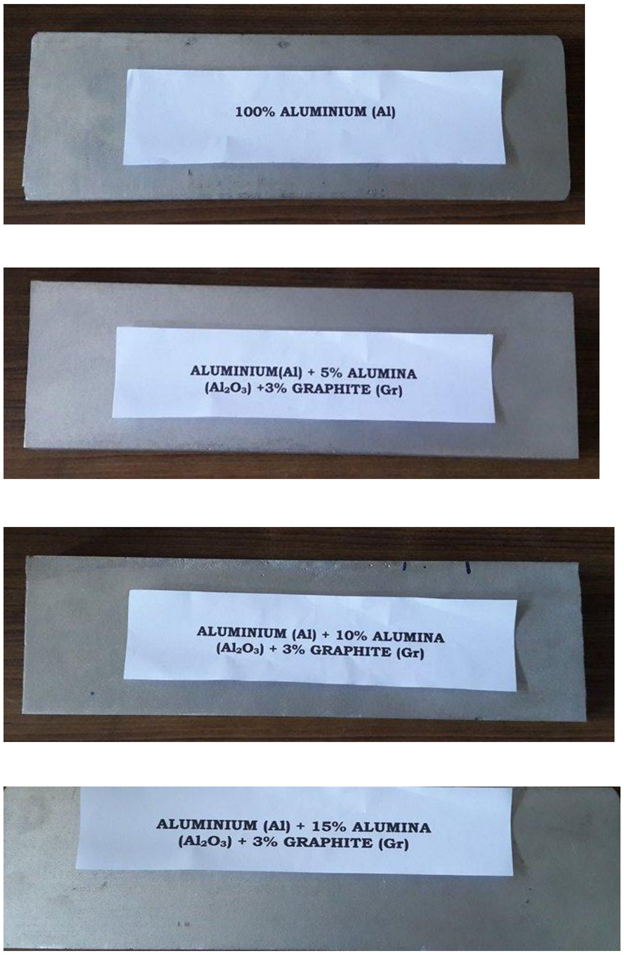


Figure 2: Fabrication of the Samples

Figure 3: Mitutoyo Roughness Machine

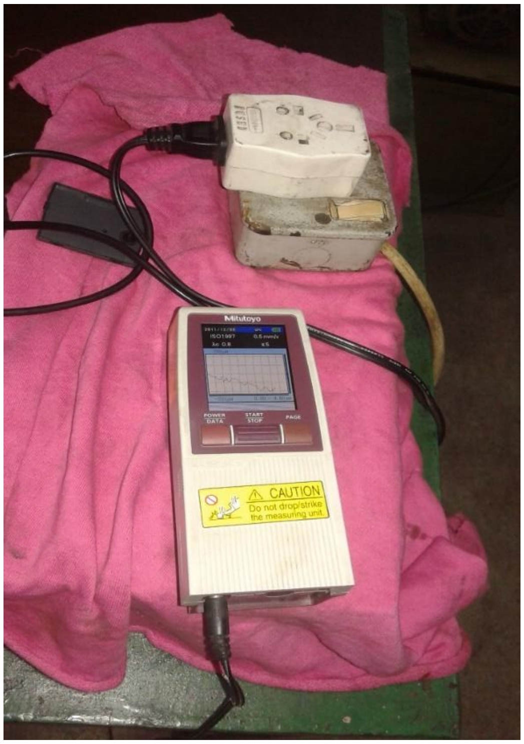


Figure 4: Machine setup for roughness measurement

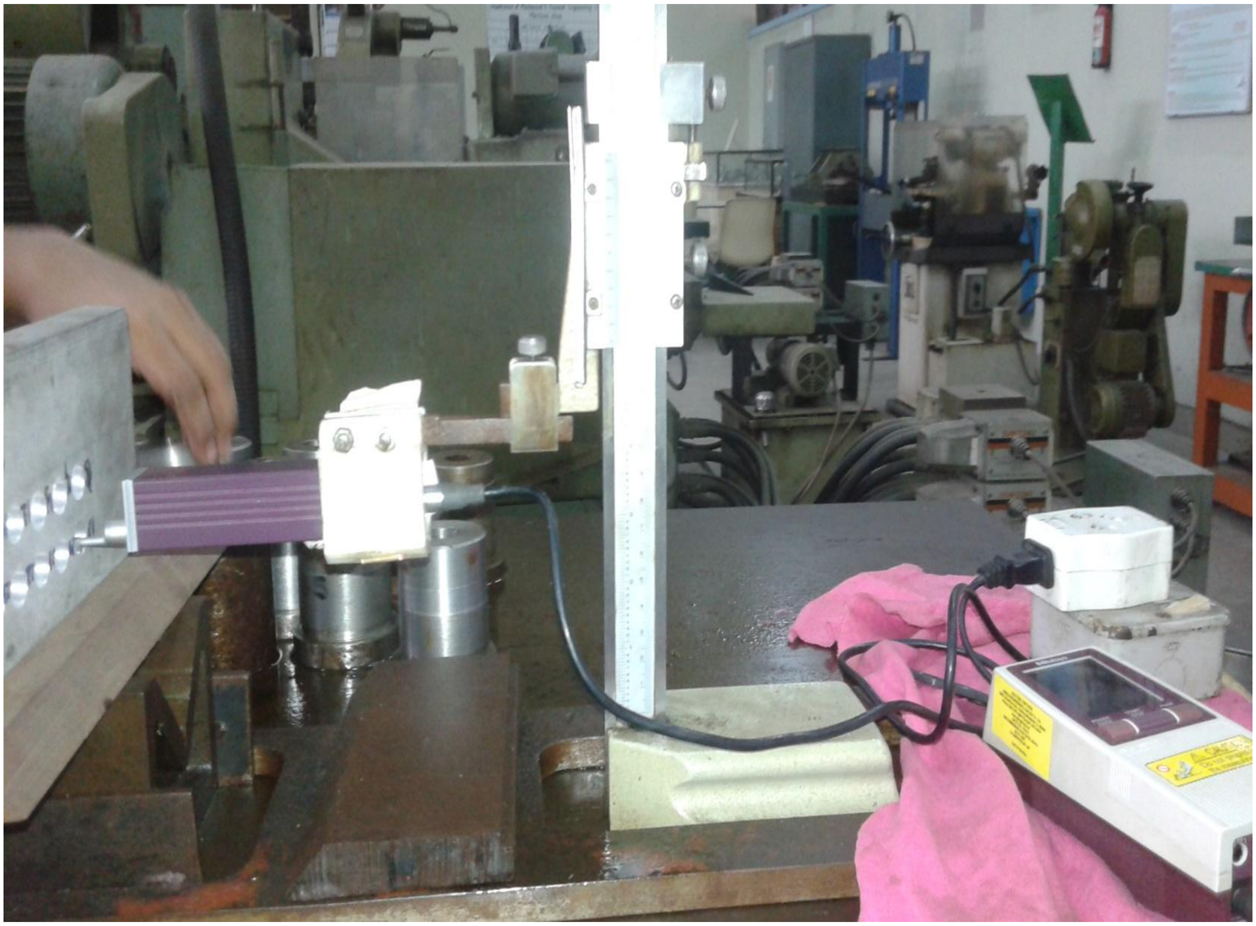


Figure 5: Image J 1.50i software

ImageJ 1.50i
Wayne Rasband
National Institutes of Health, USA
http://imagej.nih.gov/ij
Java 1.8.0_77 (64-bit)
80MB of 640MB (12%)
ImageJ is in the public domain

Fig 6: Plugging the image

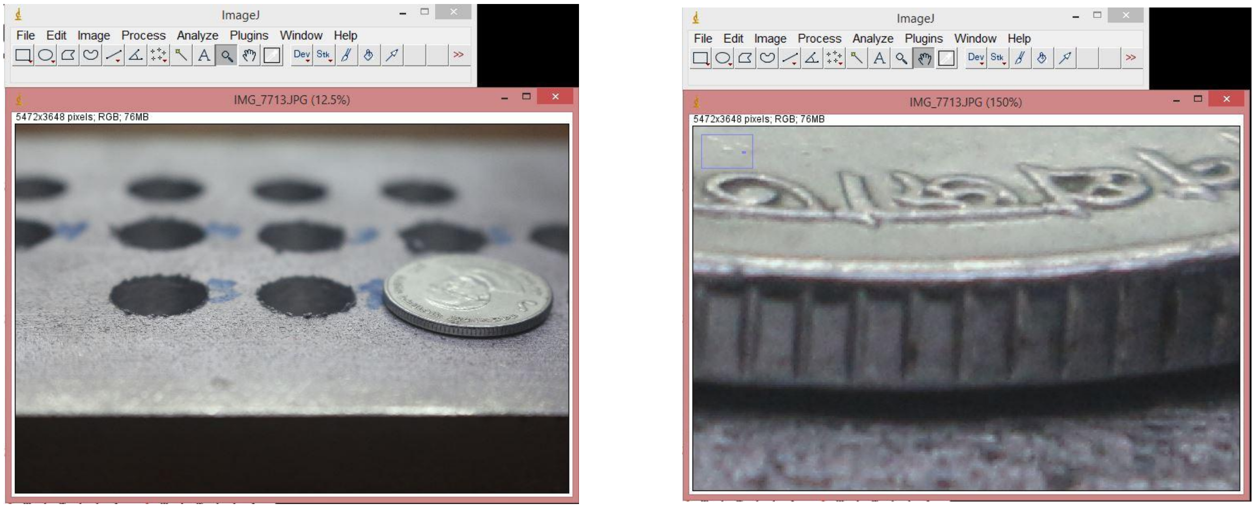
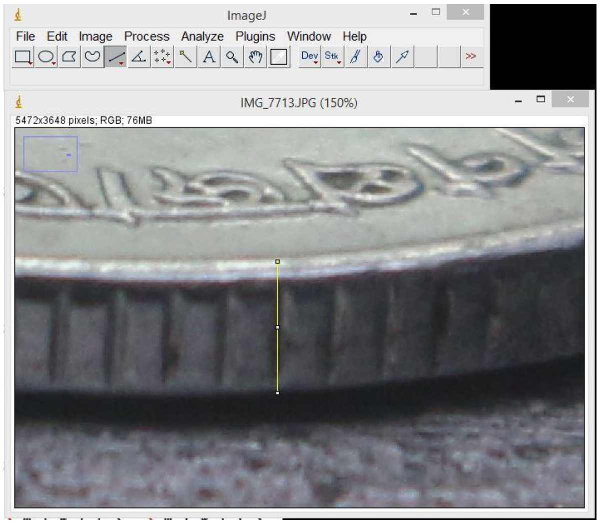
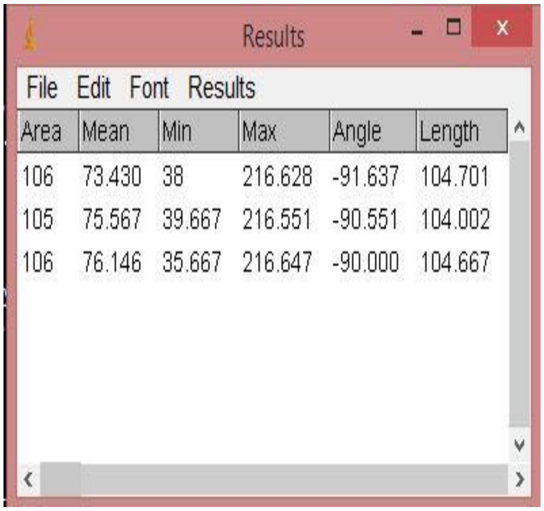
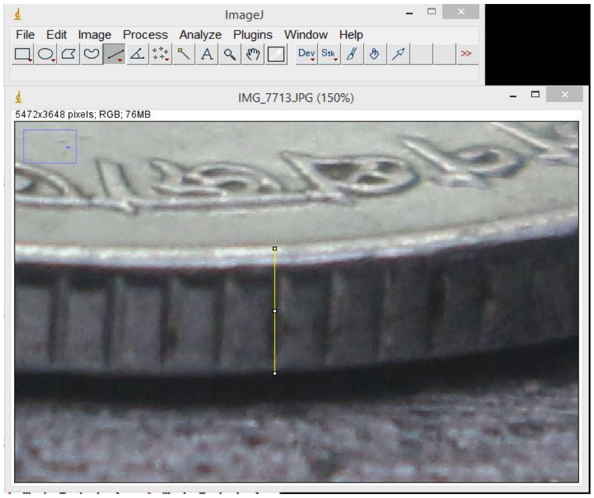


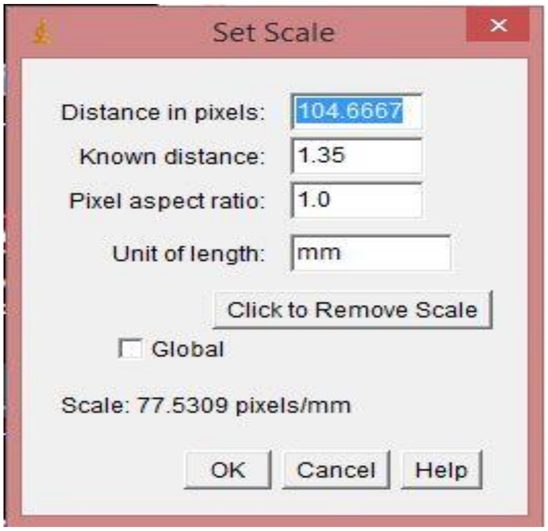
Figure 7: Setting the Scale





Area	Mean	Min	Max	Angle	Length
106	73.430	38	216.628	-91.637	104.701
105	75.567	39.667	216.551	-90.551	104.002
106	76.146	35.667	216.647	-90.000	104.667

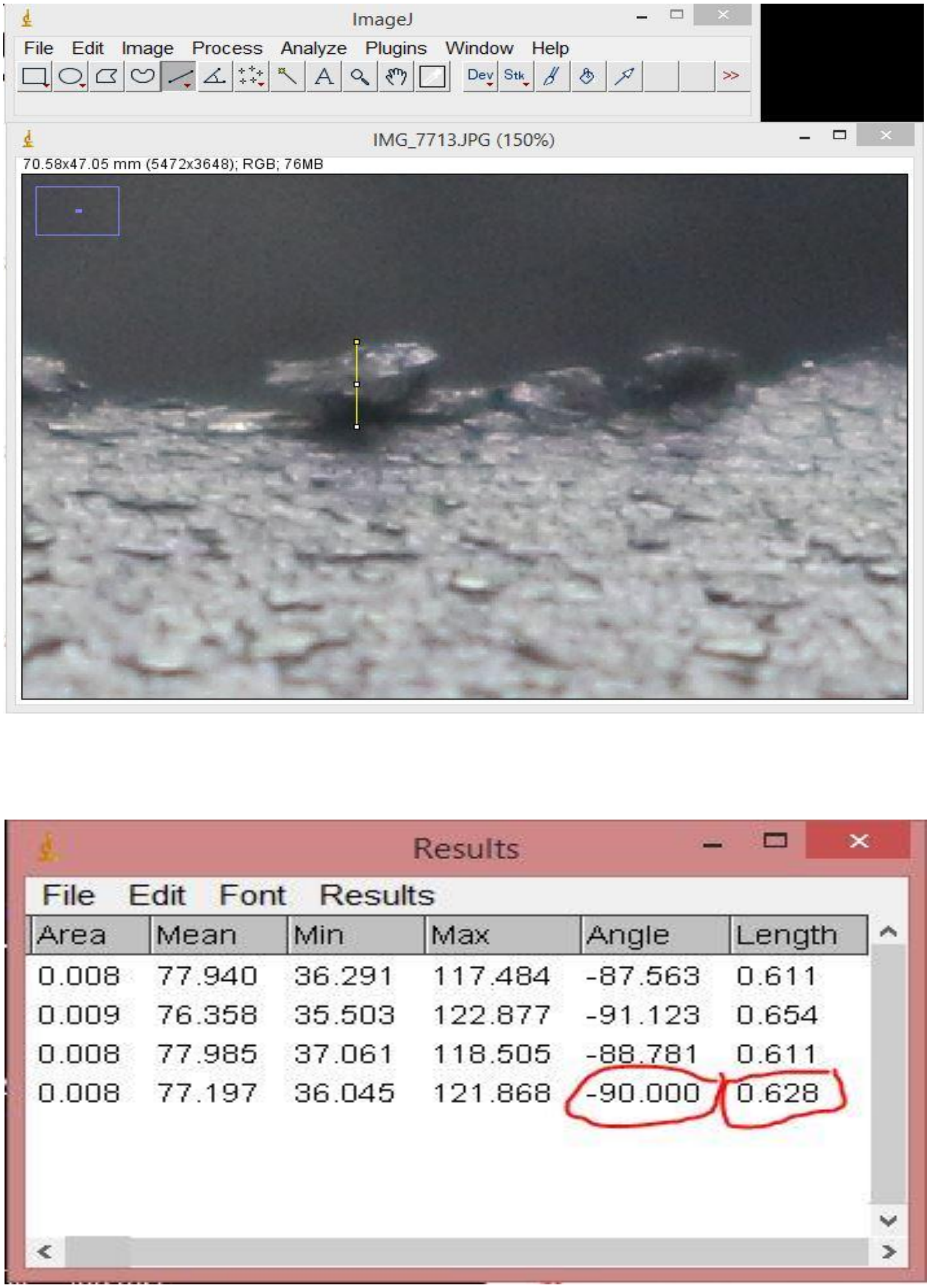




Distance in pixels: 104.6667
Known distance: 1.35
Pixel aspect ratio: 1.0
Unit of length: mm

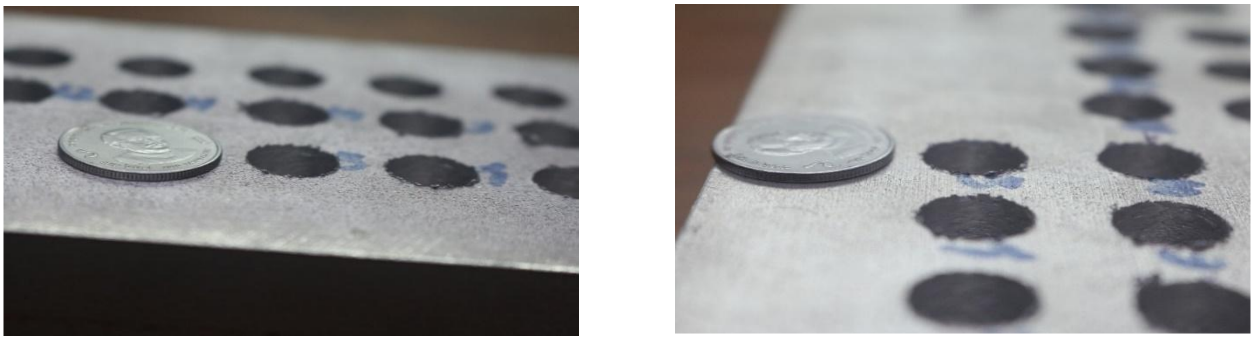
Scale: 77.5309 pixels/mm

Figure 8: Measuring the Burr Heights



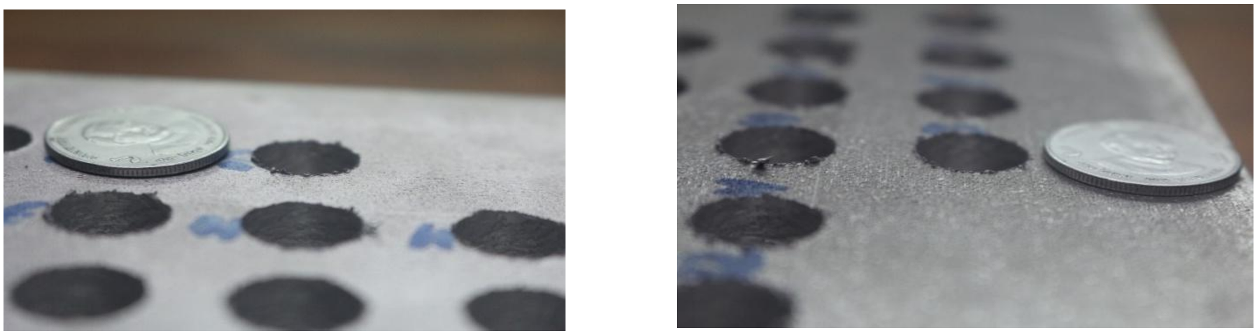
Area	Mean	Min	Max	Angle	Length
0.008	77.940	36.291	117.484	-87.563	0.611
0.009	76.358	35.503	122.877	-91.123	0.654
0.008	77.985	37.061	118.505	-88.781	0.611
0.008	77.197	36.045	121.868	-90.000	0.628

Figure 9: Burr Height Measuring Angles of the Holes



Angle#1

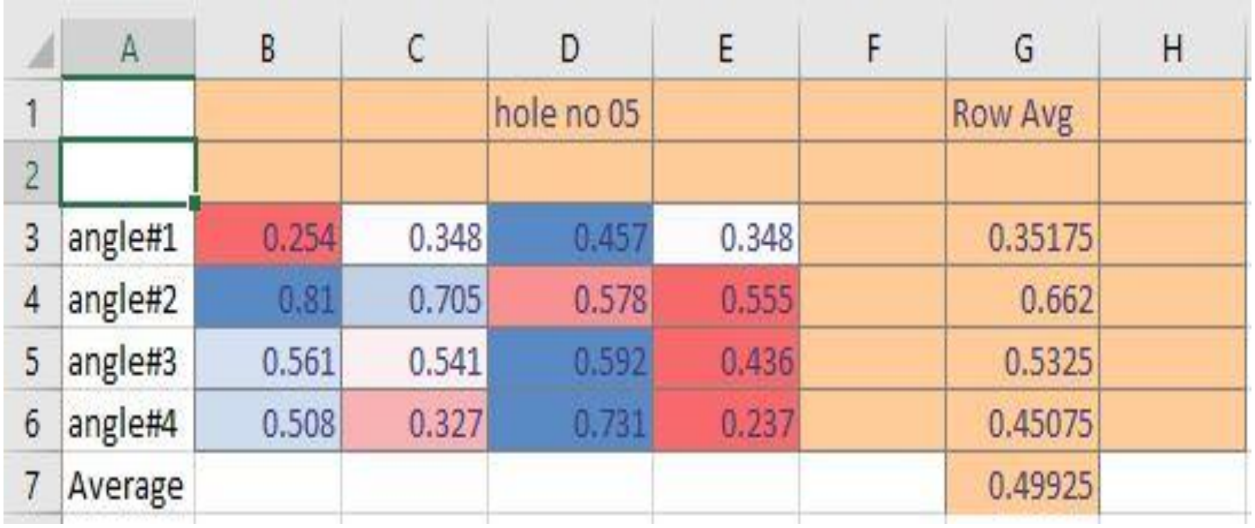
Angle#2



Angle# 3

Angle#4

Figure 10: A Sample Measured Burr Heights



	A	B	C	D	E	F	G	H
1				hole no 05			Row Avg	
2								
3	angle#1	0.254	0.348	0.457	0.348		0.35175	
4	angle#2	0.81	0.705	0.578	0.555		0.662	
5	angle#3	0.561	0.541	0.592	0.436		0.5325	
6	angle#4	0.508	0.327	0.731	0.237		0.45075	
7	Average						0.49925	

Figure 11: Surface roughness graph

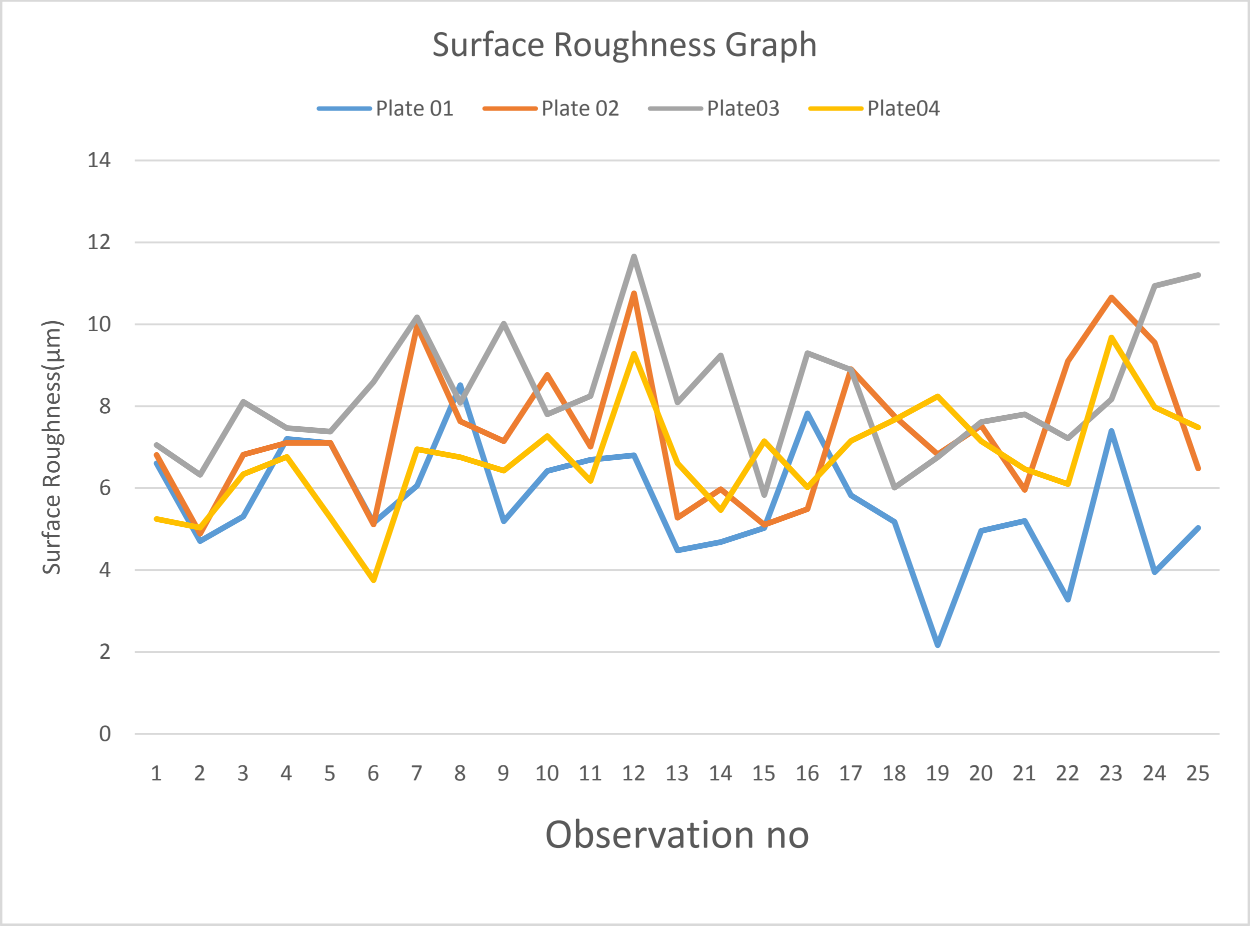
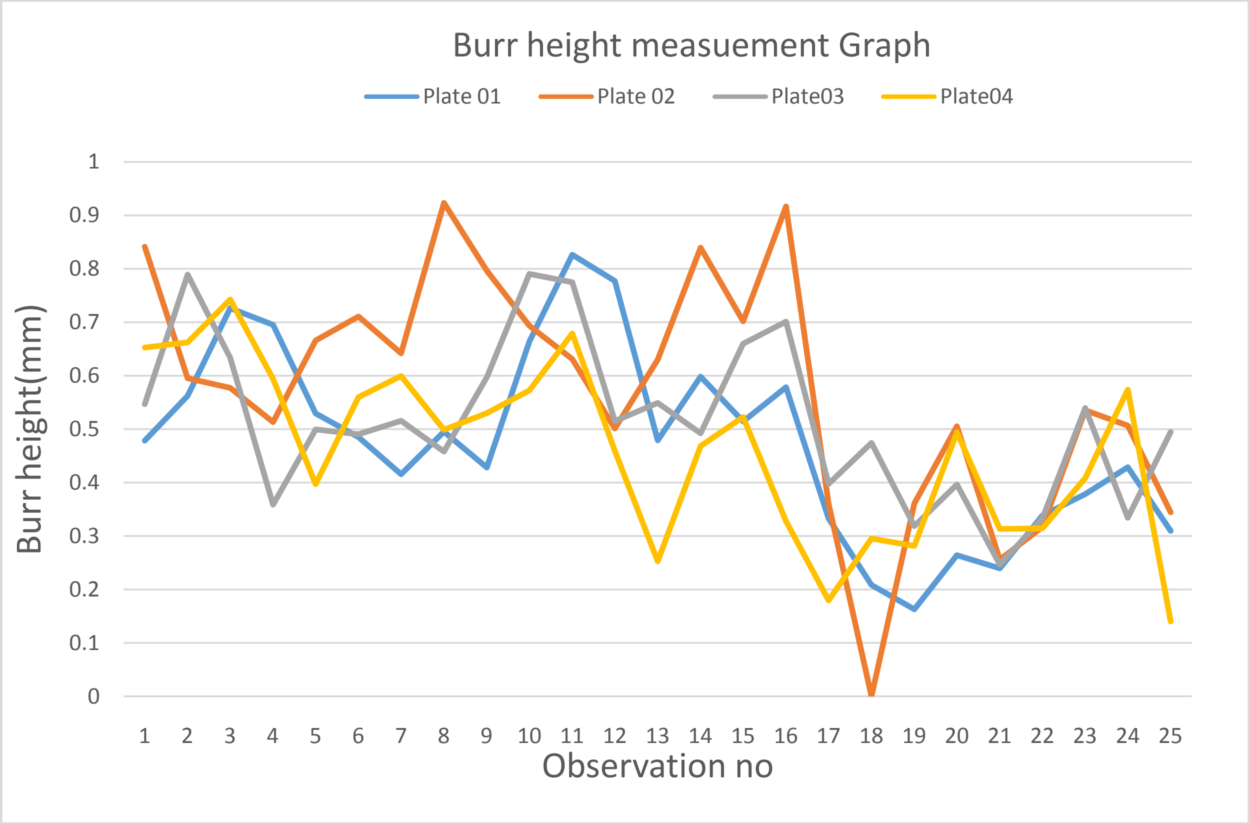


Figure 12: Burr height measurement



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