Deburring in drilled holes by EDM process-A Review

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Abstract- **In this review paper deburring operation perform by various researcher are reviewed. Burr formed in drilling operation using electrical discharge machining (EDM) and with different electrode. The process parameters involve in the deburring operations are directly affect on MRR ,EWR, SR. In many research it is found that burr removal operation of composite materials also can be done by EDM ,ECM , AJM as compare to other conventional machining. Burrs are form in most of the machining process like drilling, grinding and other modification procedss but the burr cannot eliminate.So, after the controlling process parameters it can be minimise. Electrode materials like aluminium, copper, brass, graphite can be use depending on the which deburring is performed. Burr removal is essential for functioning of product in operation so deburring using EDM provides better solution for removal burrs from workpiece materials.**

Index Terms- **Drilled hole, Deburring, Burr formation, EDM, Electrode wear.**

I. INTRODUCTION

Metal is machined using many processes to create pieces of specific shape and size. A burr is a raised edge or small pieces of mate- rial remaining attached to a work piece after a modification process.It is usually an unwanted piece of material, removed with a deburring tool in a process called “deburring”. Burrs are most commonly created after machining operations, such as grinding, drilling, milling, engraving, or turning.

Formation of burr is depending upon the workpiece material, machining conditions and tool geometry. Burrs which are an undesired, but unavoidable in most of the machining processes. Moreover, as size of hole decrease, burr problems become more difficult to resolve. The burr formation in assembly cause jamming and misalignment[10].

To eliminate this problem, several deburring methods have been introduced, including ultrasonic, magnetic abrasive, abrasive jet and electrochemical machining methods. However, these methods all have some limitations, such as mechanical damage, over–machining, changes in the material properties of the finished surface, sharp edge blunting, and the requirement for subsequent processing to remove chemical residues.

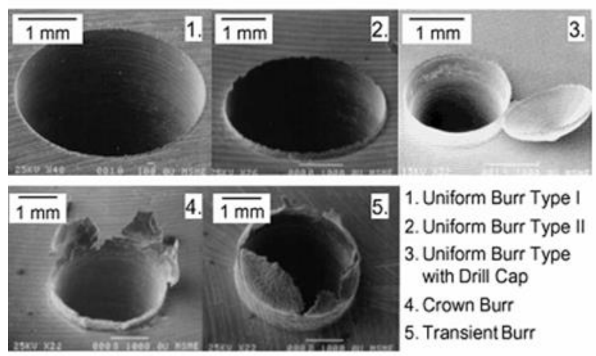


Fig.1.Types of Burr Formed in Drilling Operation

The various types of burr formed in drilling operation are shown in Fig. 1 and The uniform burr has relatively small height and thickness around the hole periphery. The crown burr has a larger and irregular height distribution around the hole. The transient burr is type of burr formed in the transient stage between the uniform burr and the crown burr[10].

II. DEBURRING

Burrs are minimized by controlling the process parameters, tool geometry, but eliminatin is not possible [13].Therefore, deburring is an important operation which mainly used for burr removal. Deburring of invisible area via conventional methods does not ensure burr removal and edge conditioning but using non–conventional techniques provides a optimum solution [12].

- Electrical deburring
- Ultrasonic deburring
- Deburring using industrial robots
- Thermal deburring
- Chemical deburring

1) Mechanical Deburring
In mechanical deburring operations the burrs are reduced or removed by mechanical abrasion. Mechanical deburring encompasses many types of processes, including cutting processes, power brushing, bonded abrasive finishing, mass finishing , abrasive blasting, abrasive flow deburring.

2) Deburring using Industrial Robots
In this process, a robot automation system has been developed for the automotive and aerospace industry. This system is composed of a robot and peripheral equipment. The most important peripheral equipment in this process is the fixture device of the work piece. Also, when the size of the work piece is bigger than the robot work envelope then robot track motion should be used [10]. So it can understand from the literature that, the deburring using industrial robots will not provide a better solution as it is complicated and costlier.

3) Chemical / Thermal deburring
Chemical deburring means a fine and super finishing of metal surfaces. In this deburring process small burrs are removed only by a chemical solution. The chemical deburring works without any external current generator.

4) Electrochemical Deburring (ECD)
Electrochemical deburring is a method that finishes the workpiece surfaces by means of anodic metal dissolution. The deburring tool is the cathode (-) that acts under DC current and in the presence of an electrolyte fluid to create the anodic reaction that removes workpiece (+)surface material in a precise manner. The electrolyte solution transfers charge in the gap between the cathode and workpiece, which causes electron transfer from the workpiece to remove surface material.
The separation distance between the cathode and the workpiece is key to regulating the material removal process.The shape of the cathode determines the final shape of the workpiece or the impression (imaging) placed upon the workpiece. The speed of material removal is dictated by the DC current applied. The amount of material removed is defined by Faraday's Laws. The material removed during the deburring process must be filtered out of the electrolyte stream in order to maintain constant electrolyte quality in the gap between the cathode and the workpiece.
Non– conventional techniques such as EDM ECD , AJM, etc. provides better solution for deburring [13].

- Burrs from drilling operations

In drilling, the burr that forms at the entrance of the hole can be a result of tearing, a bending action followed by clean shearing, or lateral extrusion. The burr that is formed when a sharp drill exits the workpiece is a Poisson burr resulting from rubbing at the margins of the drill. When a normal or worn out drill exits the uncut chip rolls, resulting in a rollover burr [18].
Kim[19] categorizes drilling burrs as uniform burr with or without a drill cap, crown burr or petal burr according to their shapes and formation mechanism. Two types of burrs, uniform burr (type I: small uniform burr, type II: large uniform burr) and crown burr, for stainless steel and three types of burrs, uniform burr (type I: small uniform burr, type II: large uniform burr), transient burr, and crown burr, for low alloyed steel were found.

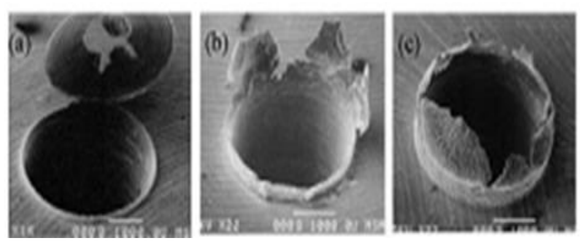


Fig.2 Types of Drilling Burr (a) Uniform (b) Crown (c) Transient
For burr formation in drilling operations Stein[20] reveals in her investigations that the constant ratio between burr height and undeformed chip thickness may be a fundamental property of work material for a particular tool geometry. This occurs in regions of undeformed chip thickness, where the tool performs a cutting rather than a plowing action. Min develops a burr formation model specific to drilling of intersecting holes. An interaction angle that defines the interaction between the cutting edge and the exit surface was proposed under the assumption that the

exit surface geometry does not change. It includes dynamic motion of the cutting edge induced by feed and speed. When the interaction angle is positive, the cutting edge exits from the workpiece and vice versa. The model can predict the likely burr formation area that can be represented as the positive interaction angle. The area increases as feed increases, speed decreases, and the exit surface angle decreases. An effective exit surface angle was proposed in order to incorporate the change of the exit surface geometry during drilling. Due to the plastic deformation at the end of a cutting process, the exit surface geometry changes. Depending on the angular position of the exit surface, the effective exit surface angle changes. A small negative exit surface angle leads to early initiation of the bending mechanism and results in a large burr. Hence, thinner parts of a workpiece may have a larger burr. The interaction angle dictates exiting and entering of the cutting edge. It thereby predicts the likely burr formation area. The effective exit surface angle defines the size of burr and shifts the likely burr formation area calculated through the interaction angle in the rotational direction of the drill[21]. Leitz develops two kinematical process models describing tool exit and entry conditions, as well as the calculation of remaining material when drilling intersecting holes. The combination of these process models and experimental results enables well funded declarations on burr position and shape depending on intersection geometry [22].

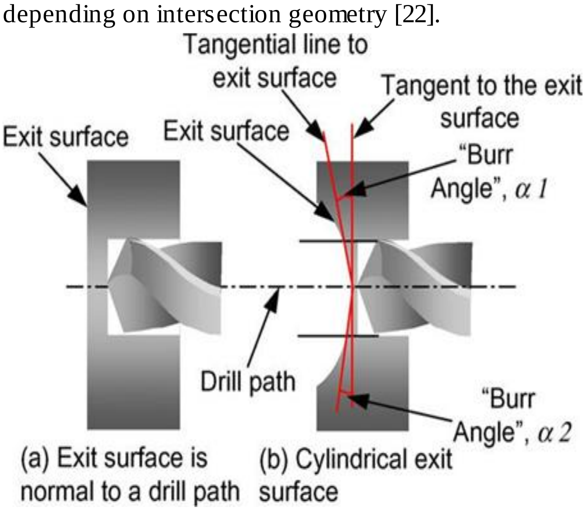


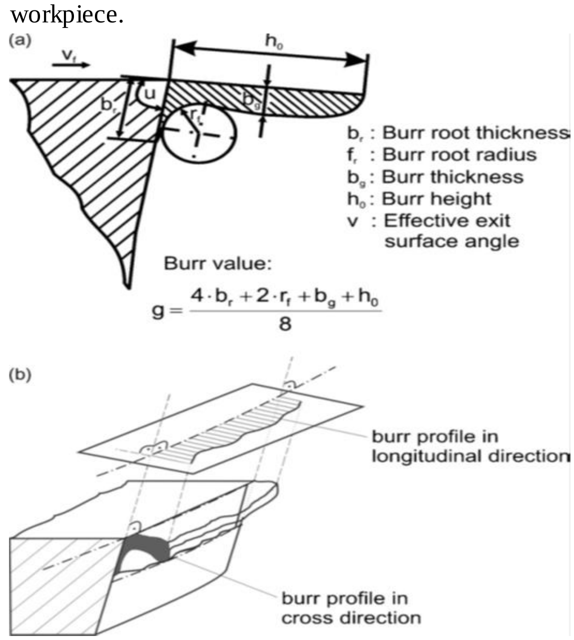
Fig.3 Burr formation when drilling intersecting holes according to Min [23].

- Burr geometry

Schafer [16] Random cross-section for describing basic burr parameters. He states that each burr can be characterized by its longitudinal and cross-sectional profile and defines the following burr descriptions and measurement categories.

- The burr root thickness bf is the thickness of the burr root area measured in the cross-section.
- The burr height h_0 is defined by the distance between the ideal edge of the workpiece and the highest point in the crosssectional area.
- The burr root radius r_f as shown in Fig. is determined by positioning a circle to the burr root.
- The burr thickness b_g describes the thickness parallel to the burr root area at a distance of r_f, as measured in the cross-section.

The longitudinal profile of a burr is not very informative in most cases, and therefore, it is rarely used to describe burrs. The length of the burr is of interest because it describes how much of the total edge length exhibits a burr. This in turn is directly related to the time necessary for deburring of workpiece.



III. DEBURRING USING EDM PROCESS

EDM is a well established non- contact machining process based on the electric energy between the electrode and the work piece accompanied by spark discharge. It is a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks). Material is removed from the work piece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the 'tool' or 'electrode', while the other is called the work piece-electrode, or 'workpiece.'The metal is removing from the work piece due to erosion case by rapidly recurring spark discharge taking place between the tool and work-piece. When a cylindrical EDM tool approaches a workpiece edge with burrs, the burr on the top plane is closest to the tool. Therefore, a plasma channel is generated between the tool and the burr. The heat transfers through the thin burr with a high aspect ratio, and thus heat energy with high intensity and short duration is concentrated in the area of the burr. Therefore, the burr is likely to be removed first when the distance between the tool and the top plane of the workpiece is adjusted appropriately.

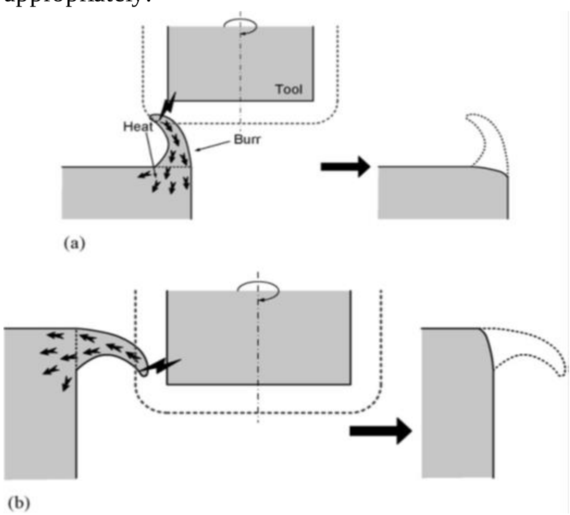


Fig5. Deburring By EDM
Deburring on a) top plane b) side plane of edge

IV. LITERATURE SURVE

1.According to Md. Mofizul Islam, Chang Ping Li And Tae Jo Ko,Dry EDM method using oxygen and air as dielectric has been proposed for the removal of burrs from CFRP composites.

• In dry electrical discharge machining (EDM), the liquid dielectric is replaced with a gaseous medium. Dry EDM reduces machining costs and environmental hazards.

•The benefits of dry EDM are low tool wear, lower discharge gap, lower residual stresses, smaller heat-affected zone, and higher MRR. The combination of oxygen EDM and a copper tool electrode leads to a higher MRR.

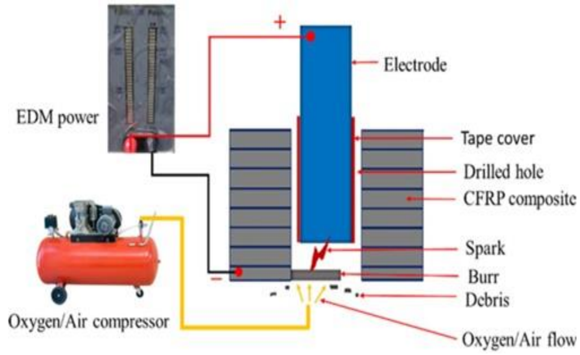
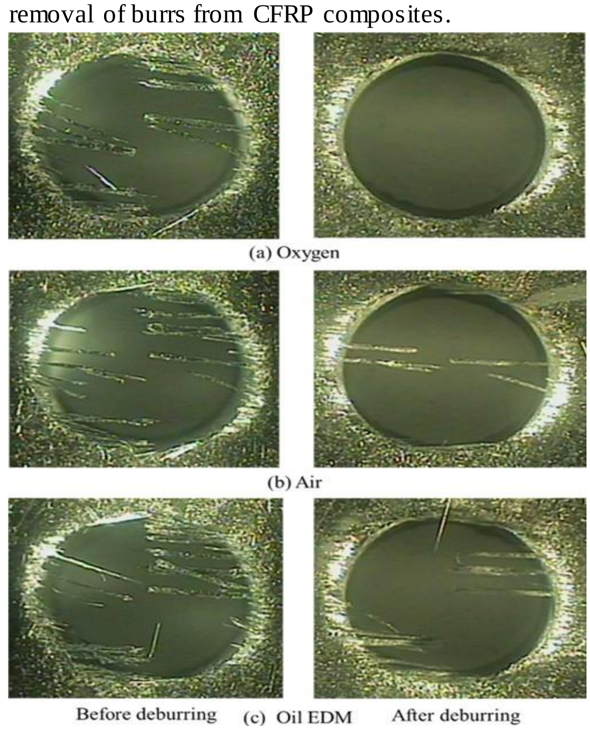


Fig.6 Schematic of dry EDM for deburring drilled holes

•Effect of Capacitances on the Deburring Performance

The MRR increase with the capacitance, voltage and gas pressure in both dry and oil EDM. Hence, Dry EDM was more effective than oil edm for the removal of burrs from CFRP composites.



• Effect of Tool Polarity on the Deburring Performance

When oxygen gas was used, the MRR with positive tool polarity is about four times greater than that with negative tool polarity. When using air, the deburring rate with positive tool polarity is three times higher than that with negative tool polarity. In conventional EDM, the MRR with positive tool polarity is also three times greater than that with negative tool polarity. When the tool was attached to the positive polarity, the MRR with oxygen was approximately three times higher than that in oil EDM, and that with air is nearly two times higher.

• Effect of Voltage on the Deburring Performance

The MRR increases moderately with the increase of voltage from 100 to 150 V in both dry and oil EDM. The MRR then increases sharply with the increase in voltage up to 220 V.

The maximum MRR was found when using oxygen, and the minimum was obtained with oil EDM at all voltages. Oxygen and air produced almost three times and two times better performance than oil, respectively.

• Effect of Gas Pressure on the Deburring Performance

The MRR increases with the gas pressure because of the high-pressure gas flow cooling the machining gap better and expels more of the debris. . In dry EDM, oxygen showed nearly 1.4 times better performance than air at all gas pressures. This shows that the gas pressure has a significant influence on the deburring performance in dry EDM.

Dry EDM was more effective than oil EDM for the removal of burrs from CFRP composite.

2. Uday A. Dabade

Effect Of Edm Process Parameters For Burr Removal Of Drilled Holes In Inconel-718

• Tool Wear Rate (TWR)

From the ANOVA, it is observed that current and pulse on time (POT) is most significant parameter with Brass electrode. The interaction between current and pulse on time (POT) as well as pulse on time (POT) and dielectric flow rate (DFR) are significant parameters. Whereas, with Aluminium electrode only current is significant parameter and interactions are non-significant.

• Quality of Burr Removal by Visual Inspection

The quality of deburred hole is good at lower level of discharge current and it deteriorates with increase in current due to undercut of drilled holes.

• Increase in current increases TWR for the brass and aluminium electrodes due to more heat energy produced in electrode interface which leds to melting and evaporation of electrode. And quality of burr removal using brass electrode is better as compared to aluminum electrode.

• With increasing pulse on time (POT), the wear increases for the brass electrode. This is due to short pulse which causes less vaporization whereas, long pulse duration cause the plasma channel to expand.

• The quality of burr removal using Brass electrode is better as compared to Aluminum electrode.

• Aluminum electrode is not recommended for burr removal of drilled holes by EDM process because of its inefficient cutting property at low discharge current values.

3. Pretesh John And Rahul Davis

Performance Study Of Electrical Discharge Machining (Edm) Process In Burr Removal Of Drilled Holes.

Researcher use the optimization techniques.

The Grey relational analysis is a method to analyze the relational grade for discrete sequences. This is unlike the traditional statistics analysis handling the relation between variables.

• Optimal parameters for deburring on OHNS with copper electrodes were 15-amp discharge current, 10-μ sec pulse time on and 6-μ sec pulse time off.

• Optimal parameters for deburring on OHNS with brass electrodes were 15-amp discharge current, 11-μ sec pulse time on and 8-μ sec pulse time off.

4. J.C. Aurich (1)a,*, D. Dornfeld (1)b, P.J. Arrazola (3)c, V. Franke a, L. Leitz a, S. Min (2)b Burrs Analysis, control and removal FEM analysis and burr formation simulation Finite element method analysis can be used as a tool to understand and predict burr formation. The current state of research and future trends of burr formation simulation and modeling are outlined in Several investigations have been carried out in order to simulate drilling burrs. A three-dimensional finite element model is developed to investigate the mechanisms of drilling burr formation with a backup material. This model also predicts cutting forces in drilling, and explains the correlation of thrust force and burr size. Simulation results show that negative shear situation near the edge of the hole

and gap formation are the primary mechanisms in drilling burr formation with backup material.

• Parameters with influence on burr formation

In drilling of intersecting holes is investigated. The workpiece exit angle in drilling is an important factor in determining burr size and shape. The shape of burrs around onaxis holes is more uniform than the shape for off-axis holes, and this difference is probably determined by the variation in exit angles between the two configurations. The feed and the feed/ cutting speed interaction, in addition to the exit angle, are also influential factors for the burr size in both on-axis and off-axis intersecting hole drilling. Beier as well reveals several parameters to reduce burr formation when drilling intersecting holes. Factors which influence microburr size and shape are investigated in increasing levels of feed rate, spindle speed and tool wear change the shape of the burr and increase burr size.

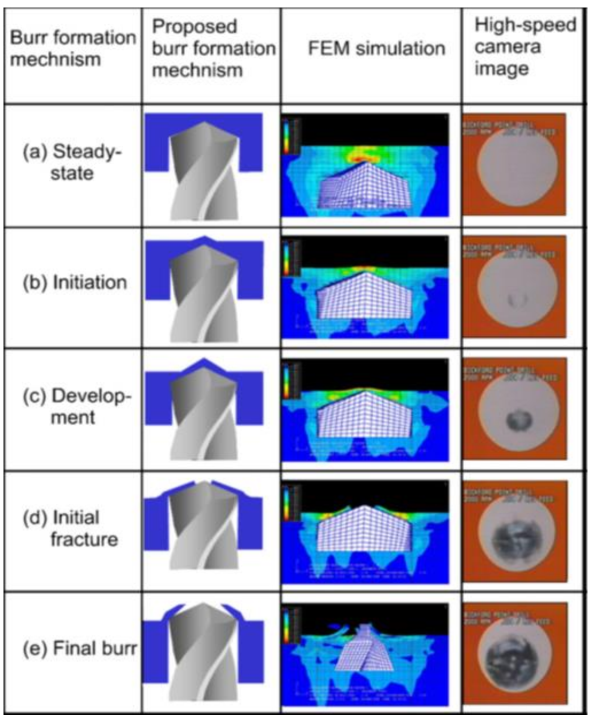


Fig.8 FEM simulation of burr formation in drilling.

As a result of research into burrs is that burr control rather than burr avoidance is a promising approach. A controlled burr may be either acceptable due to its small size and reproducible nature or it may be a burr which can be safely deburred with a standardized automated procedure.

5. Seyed Ali Niknam, Yasser Zedan and Victor Songmene Machining Burrs Formation & Deburring of Aluminium Alloys

• Most aluminium alloys, whether wroughts or casts, can experience burr formation during machining processes; The shape and the size of this burr will depend on the alloy composition and conditions, its mechanical properties, but also on type of machining operation, tooling used, machining parameters, and machining conditions and strategies. Using very low feed rates on a material with high ductility may generally lead to higher burr size.

6. Chandramouli S.a*, Eswaraiah K.b

Optimization of EDM Process parameters in Machining of 17-4 PH Steel using Taguchi Method

• Effect of input parameters on MRR and SR

1. Pulse current: The effect of pulse current on metal removal rate shows that as the pulse current increases. The increase in MRR, increase in pulse current is due to enhancement of spark energy that facilitates the action of melting and vaporization. This action results in advancing the impulsive force in the spark gap and thereby increasing the MRR. The surface roughness parameter increases with the increase in current rate due to increases in MRR

2. Pulse on time: In the present study MRR decreases with increase in pulse on time, due to the amount of energy generated at high pulse on time not utilizing for removing the metal. At high values of pulse on current, instead of sparking in the inter electrode gap arcing observed. The surface roughness increases with decrease of pulse on time due to arcing between tool and work instead of sparking.

3. Pulse off time: MRR increases with increase in pulse off time since sufficient time to flushing the eroded particles from gap between tool and work piece. The surface roughness increases with increase of pulse off time due to increase in MRR.

4. Lift time: MRR decreases with increase in lift time, due to decrease in actual time of machining the work piece. the surface roughness increases with increase of tool lift.

6. Md. Mofizul Islam1, Chang Ping Li1, Sung Jae Won1, Tae Jo Ko1

• Burr formation in drilling CFRP

Burr generation influenced by machining parameters (cutting speed, rpm; Feed rate etc.), fibre orientation, tool geometry (point angle, tool wear), tool type, tool material, drilling types etc. The burrs are mainly formed by some fibers without been cut off due to the retreat in the feed direction of the drill bit. The angle between the cutting speed direction and the fiber orientation is the main cause for the generation of exit burr and workpiece vibration and temperature increasing in the exit are the another reasons. While drilling, the separation of the composite layers may occur when the drilling tool can push through the front-end materials. When the bending stress exceeds the bending strength limit of the work material, the uncut fiber layers occur fracture at the bottom, which causes the formation of burrs at the bottom side of the composites. Mostly, during drilling the burr is generated in the entrance and exit side of the machined hole, of which the exit side burr is the greatest problem.

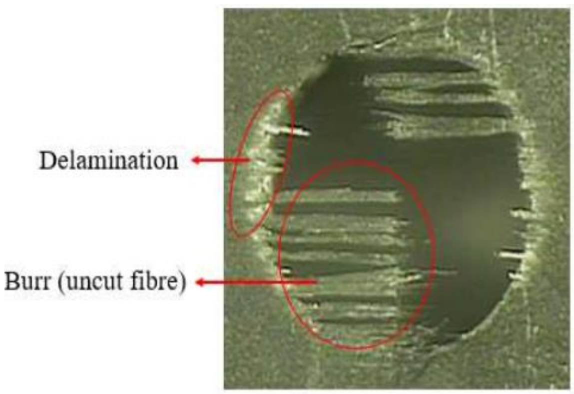


Fig.9 Generated burrs after drilling of unidirectional CFRP composite (a) and defined burr geometry.

Four types of cylindrical tool were used as an electrode for EDM deburring process. The copper electrode obtained the highest performance in terms of deburring time and materials removal rate whereas aluminium electrode showed the lowest performance. For EDM deburring method, the copper electrode proved better than others electrode. There are no morphological changes were observed in the drilled hole wall and face after deburring by the proposed method.

V. TOOL ELECTRODE

1. Brass: Brass is the generic term for a range of copper-zinc alloys with differing combinations of properties, including strength, machinability, ductility, wear-resistance, hardness,colour, antimicrobial, electrical, and thermal conductivity, corrosion resistance. Brass has higher malleability than bronze or zinc. The relatively low melting point of brass (900 to 940 °C, 1652 to 1724 °F, depending on composition).

2. Copper: Copper has properties, such as its high electrical conductivity, tensile strength, ductility, creep (deformation) resistance, corrosion resistance, low thermal expansion, high thermal conductivity, solder ability, and ease of installation. Copper is a chemical element with symbol Cu and atomic number. It is a ductile metal with very high thermal and electrical conductivity. Pure copper is soft and malleable.

3. Steel: The major constituent of steel is iron therefore The strength of steel can be increased by the addition of alloys such as manganese, niobium and vanadium. However, these alloy additions can also adversely affect other properties, such as ductility , toughness and weldability. The Melting point of steel is 1370ºC to 1500ºC.

4. Graphite: It is easy to machine.
It is very resistant to thermal shock. It has a low coefficient of thermal expansion (3 times lower than copper) which guarantees stability of electrode geometry during electro discharge machining. It is available in large blocks an it does not melt, but goes directly from the solid state to the gaseous at 3,400°C,which reduces wear. Its density is 5 times lower than that of copper, which results in lighter electrodes and it provides a higher metal removal rate than copper with less wear.

VI. METHODOLOGY

For the proposed work, the following Methodology was adopted:

- To prepare the specimen
- To prepare the electrode tools
- To perform Drilling operation on the specimen To investigate the following:

a) MRR
b) SR

•To perform EDM operation to remove burrs with defined parameters
•To investigate the following after EDM process:
a) MRR
b) SR
•To find optimal results through Grey relational analysis based calculation

VII. PROCESS PARAMETERS

a) Current (discharge)
b) Pulse On Time
c) Electrode Polarity
d) Dielecric fluid
i) Oil
ii) Kerosene
iii) Deionized Water
iv) Dry (oxygen or air)

VIII. CONCLUSION

Burrs are form in most of the machining process but cannot eliminate it but after the controlling process parameters it can beminimise. Burr removal is essential for functioning of product in operation so deburring using EDM provides better solution for removal burrs.

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