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A Review on Effect of Process Parameters on Electric Discharge Machining

S.A. Sayyad[1], A.N. Chapgaon[2]

[1]PG Student,Departmentof Mechanical Engineering, Ashokrao Mane Group of Institutions, ShivajiUniversity.

[2]Department of Mechanical Engineering.AshokraoManeGroupof Institutions,Shivaji, University

Abstract: The Electric discharge machining (EDM) is one of the most common and most accepted non traditional machining processes used. It is a electro-thermal process and is based on the eroding effect of an electric spark on both the electrode and workpiece. It is a thermal erosion process where metal removal takes place by a series of recurring electrical discharges between a cutting tool acting as an electrode and a conductive workpiece, in the presence of a dielectric fluid. This discharge occurs in a voltage gap between the electrode and workpiece. EDM technology is increasingly being used in tool, die and mould making industries, for machining of heat treated tool steels and advanced materials (super alloys, ceramics, and metal matrix composites) requiring high precision, complex shapes and high surface finish.

Keywords— EDM, Machining Process, MRR, TWR, SR, Discharge current, Spark on time, Applied Voltage.

I. INTRODUCTION

It was originally observed by Joseph Priestly in 1770, EDM Machining was very imprecise and riddled with failures. Commercially developed in the mid 1970s, wire EDM began to be a viable technique that helped to shape the metal working industry that we see today. In the mid 1980s.The EDM techniques were transferred to a machine tool. This migration made EDM more widely available and appealing over traditional machining processes. Electric discharge machine (EDM) is commonly used in tool, die and mould making industries for machining heat-treated tool steel materials. The heat-treated tool steels material are difficult-to-cut material when using conventional machining process. One of the main problems in electrical discharge machine (EDM) is high rate of tool wear . The wear ratio defined as the volume of metal lost from the tool to the volume of metal removed from the work material. Wear ratio varies with the tool and work materials used. If the rate of tool wear is high then the material is easy to wear and not good for machining performance .Electric Discharge Machining (EDM) is a Process, where electrical energy is used to generate electrical spark and material is removed mainly due to thermal energy of the spark. The Heat from the discharge vaporizes minute particles of workpiece material, which are then washed from the gap by the continuously flushing dielectric fluid.EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Work material to be machined by EDM has to be electrically conductive[1].

A. Principle of EDM

In this process the metal is removed from the work piece due to erosion cause by rapidly recurring spark discharge between the tool and work piece. The figure below shows the mechanical set up and electrical set up and electrical circuit for electro discharge machining. A thin gap about 0.025mm is maintained between the tool and work piece by a servo system shown in figure. Both tool and work piece are submerged in a dielectric fluid .Kerosene/ EDM oil/ deionized water is very common type of liquid dielectric although gaseous dielectrics can also be used in certain Case[2].

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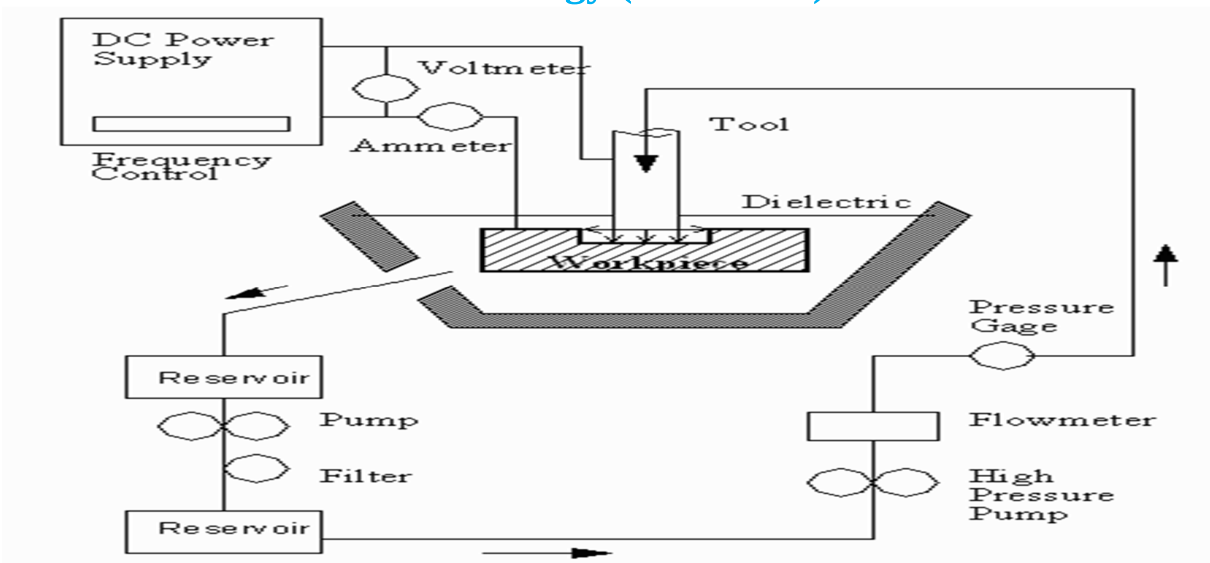

Fig.1 : Diagram of the Principle of operation of EDM Process

The tool is made cathode and work piece as anode. When the voltage across the gap becomes sufficiently high it discharges through the gap in the form of the spark in interval of from 10 of micro seconds. The positive ions and electrons are accelerated due to the heat, producing a discharge channel that becomes conductive. It is just at this point when the spark jumps causing collisions between ions and electrons and creating a channel of plasma. A sudden drop of the electric resistance of the previous channel allows current density to reach very high values producing an increase of ionization and the creation of a powerful magnetic field. The moment spark occurs sufficiently pressure is developed between work and tool as a result of which a very high temperature is reached and at such high pressure and temperature some part of metal is melted and eroded. Such localized extreme rise in temperature leads to material removal. Material removal occurs due to instant vaporization of the material as well as due to melting.

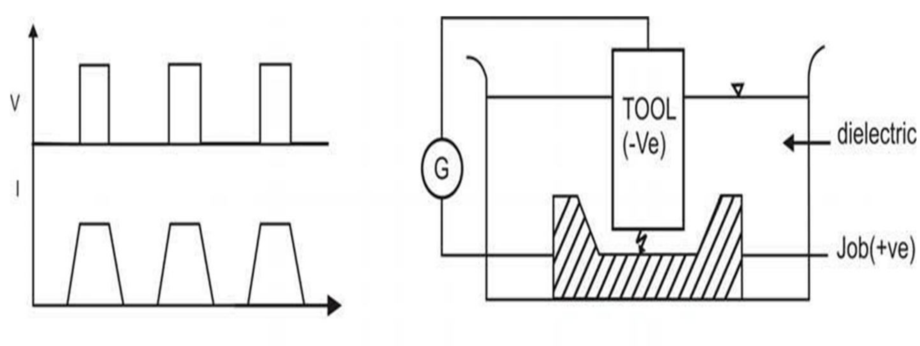

Fig.2 :Figure to show the charge on tool and the workpiece

As the potential difference is withdrawn as shown in Fig., the plasma channel is no longer sustained. As the plasma channel collapse, it generates pressure or shock waves, which evacuates the molten material forming a crater of removed material around the site of the spark.

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B. Principles of Operation

The basic components of an EDM system are illustrated in figure. The workpiece is mounted on the table of the machine tool and the electrode is attached to the ram of the machine. A DC servo unit or hydraulic cylinder moves the ram (and electrode) in a vertical motion and maintains proper position of the electrode in relation to the workpiece. The positioning is controlled automatically with extreme accuracy by the servo system and power supply.

During normal operation the electrode never touches the workpiece, but is separated by a small spark gap. During operation, the ram moves the electrode toward the workpiece until the space between them is such that the voltage in the gap can ionize the dielectric fluid and allow an electrical discharge (spark) to pass from the electrode to the workpiece. These spark discharges are pulsed on and off at a high frequency cycle and can repeat 250,000 times per second. The spark discharge (arc) always travels the shortest distance across the narrowest gap to the nearest or highest point on the workpiece. The amount of material removed from the workpiece with each pulse is directly proportional to its energy[3].

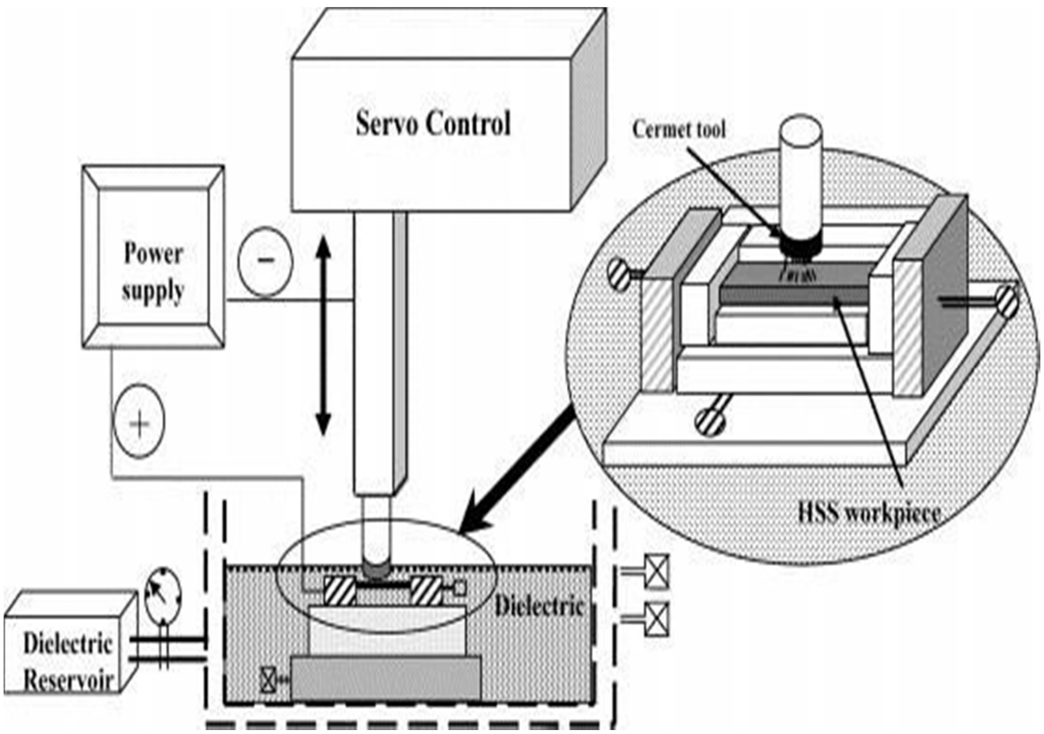

Fig.3: Servo control mechanism representation in EDM

Each discharge melts or vaporizes a small area of the workpiece surface. This molten metal is then cooled in the dielectric fluid and solidifies into a small spherical particle (swarf) which is then flushed away by pressure/motion of the dielectric. The impact of each pulse is confined to a very localized area, the location of which is determined by the form and position of the electrode. Both the workpiece and electrode are submerged in a dielectric fluid which acts as an electrical insulator to help control the spark discharges.

In EDM, the dielectric fluid also performs the function of a coolant medium and reduces the extremely high temperatures in the arc gap. More importantly, the dielectric fluid is pumped through the arc gap to flush away the eroded particles between the workpiece and the electrode. Proper flushing is critical to high metal removal rates and good machining conditions.

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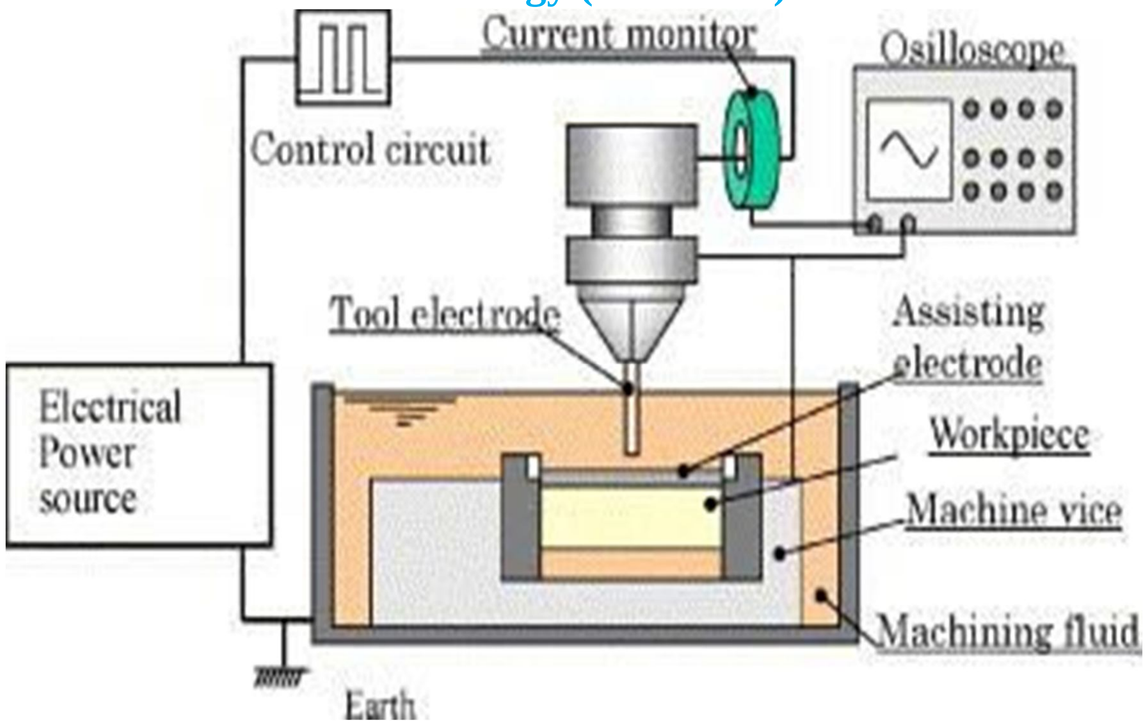

Fig.4: Complete EDM Process Representation

II. PARAMETRIC EFFECT ON EDM PROCESS

A. Spark On-time (pulse time or Ton)

It is the duration of time the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this on-time. This energy is controlled by the peak current and the length of the on-time.

Manish Vishwakarma, *et al.* [4] The purpose of this paper is to determine the optimal factors of the electro-discharge machining (EDM) process investigate feasibility of design of experiment techniques. The work pieces used were rectangular plates of AISI 4140 grade steel alloy. The study of optimized settings of key machining factors like pulse on time, gap voltage, flushing pressure, input current and duty cycle on the material removal, surface roughness is been carried out using central composite design. The output responses measured were material removal rate (MRR) and surface roughness. Mathematical models are proposed for the above responses using response surface methodology (RSM).The results reveals that MRR is more influenced by peak current, duty factor. Finally, the parameters were optimized for maximum MRR with the desired surface roughness.

Sanchez *et al.* [5] have presented a study attempts to model based on the least squares theory, which involves establishing the values of the EDM input parameters namely peak current level, pulse-on time and pulse-off time to ensure the simultaneous fulfillment of material removal rate (MRR), electrode wear ratio (EWR) and surface roughness (SR). The inversion model was constructed from a set of experiments and the equations formulated in the forward model and In this forward model, the well-known ANOVA and regression models were used to predict the EDM output performance characteristics, such as MRR, EWR and SR in the EDM process for AISI 1045 steel with respect to a set of EDM input parameters.

B. Discharge current (current Ip)

Current is measured in amp allowed per cycle. Discharge current is directly proportional to the Material removal rate.

Sohani *et al.* [6] investigated the effect of process parameters like pulse on time, discharge current, pulse off time and tool area through the RSM methodology for effect of tool shape such as triangle, square, rectangle and circular. The mathematical model was developed for MRR (material removal rate) and TWR (tool wear rate) using CCD in RSM. The ANOVA has been used for testing the adequacy of model for the responses. It also resulted that circular tool shape was best followed by triangular, rectangular and square cross sections. Interaction between discharge current and pulse on time was highly effective term for both TWR and MRR.

Habib [7] presented an investigation on EDM process to form a mathematical modeled equation for material removal rate (MRR), electrode wear ratio (EWR), gap size (GS) and surface roughness (Ra). The adequacy of the modeled equation has been checked by using ANOVA (Analysis of variance). The input parameters were taken as pulse on-time, peak current, gap voltage and SiC particles percentage. He concluded that MRR increases with the increase of pulse on-time, peak current and with gap voltage and it decreases with the decrease of SiC percentage. He modeled equations for the four responses by using RSM methodology.

C. Voltage (V)

It is a potential that can be measure by volt it is also effect to the material removal rated and allowed to per cycle

Rao *et al.* [8] conducted the experiments by considering the simultaneous effect of various input parameters varying the peak current and voltage to optimizing the metal removal rate on the Die sinking electrical discharge machining (EDM). The experiments were carried out on Ti6Al4V, HE15, 15CDV6 and M-250.

D. Spark Off-time (pause time or Toff)

The duration of time (μs) between the sparks . This time allows the molten material to solidify and to be wash out of the arc gap. This parameter is to affect the speed and the stability of the cut. Thus if the off-time is too short, it will cause sparks to be unstable.

Mandal *et al.* [9] made an attempt to model and optimize the complex electrical discharge machining (EDM) process using soft computing techniques. Artificial neural network (ANN) with back propagation algorithm is used to model the process. A large number of experiments have been conducted with a wide range of current, pulse on time and pulse off time. The MRR and tool wear have been measured for each setting of current, pulse on time and pulse off time.

E. Duty cycle (τ)

It is a percentage of the on-time relative to the total cycle time,This parameter is calculated by dividing the on-time by the total cycle time.

Kansal *et al.* [10] aimed to optimize the process parameters using Response surface methodology to plan and analyze the experiments of powder mixed electrical discharge machining (PMEDM). Spark off-time, duty cycle, peak current and concentration of the silicon powder added into the dielectric fluid of EDM were chosen as variables to study the process performance in terms of material removal rate and surface roughness.

III. CONCLUSIONS

Process parameters do not have same effect for every response. Significant parameters and its percentage contribution changes as per the behavior of the parameter with objective response.

MRR increased linearly with the increase in current .For pulse on time the MRR first increased with linearly with increase in pulse off time, MRR decreased insignificantly.

For SR the most significant factor was again current followed by pulse on time and lastly the pulse off time.SR increased significantly with the increase in current in a nonlinear fashion. For increase in pulse on time SR increased. SR is decrease with respect to increase in Pulse off time .Surface roughness shows a marked improvement with increase in pulse off time.

In the case of Tool wear rate the most important factor is peak current then pulse on time and after that pulse off time.

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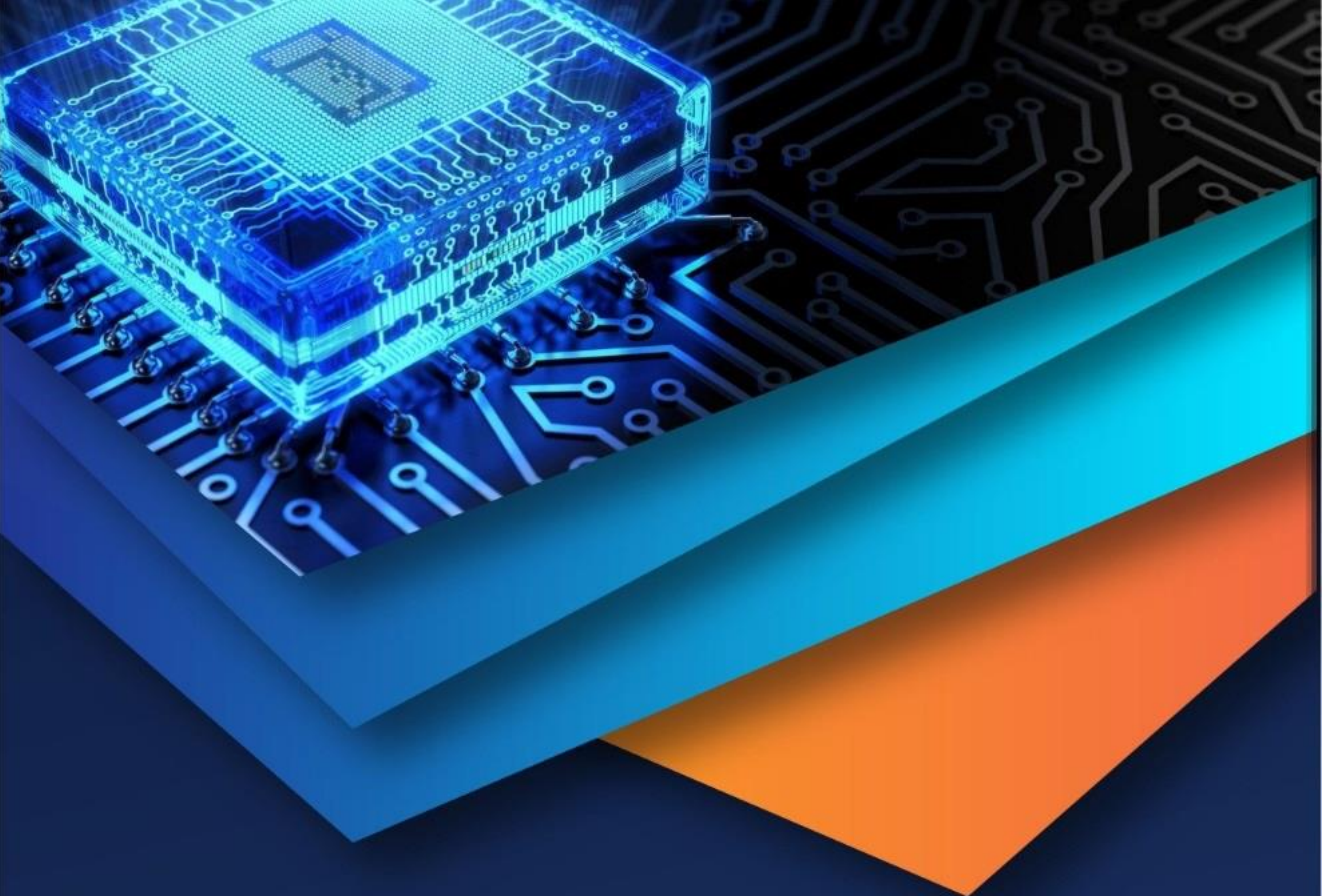

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