Available Online at http://www.journalajst.com

ISSN: 0976-3376

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

Asian Journal of Science and Technology
Vol. 08, Issue, 12, pp.6928-6941, December, 2017

RESEARCH ARTICLE

EXPERIMENTAL ANALYSIS AND THEN OPTIMIZATION OF MACHINING INCONEL 600 ALLOY IN SPARK MACHINING

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ARTICLE INFO

Article History:
Received 20th September, 2017
Received in revised form
21st October, 2017
Accepted 16th November, 2017
Published online 28th December, 2017

Key words:
Die -Sinker SM,
Material Removal Rate,
Tool Wear Rate & Surface roughness.

ABSTRACT

Spark machining is one of the non traditional machining processes which is based on thermo electric energy between the specimen and then an electrode. In this work it scrutinizes the machining characteristics of Inconel 600 using Spark machining method with Brass & Copper electrode. Taguchi's method has been adopted as a strategy of experiments technique for tentative investigation. Certain experiments have been carried out to study the effect of each parameter on the machining characteristics, and then to foretell the optimal choice for each SM parameters such as peak current, pulse on time, pulse off time and then Surface Roughness. Experiments have been designed as per Taguchi's L16 orthogonal array. Analysis of variance is used to find the level of impact of machining parameters. Machining responses such as the metal removal rate, Tool wear rate, surface roughness the tool was studied while machining the Inconel 600 with copper & Brass electrode. The selection of suitable kind of electrode can reduce the cost of machining. So, in this paper Die-Sinker SM using brass & Copper electrode has been done for optimizing performance parameters and then reducing cost of manufacturing, finally it is found that a Copper electrode give better performance in certain characteristics.

INTRODUCTION

Spark machining is a well-established machining option available for manufacturing geometrically complex or hard material parts that are extremely difficult to machine by conventional machining processes. A little crevice between the specimen and then the electrode delivers the Erosion pulse discharge. This expels the undesirable material from the parent metal through melting and then vaporizing in presence of dielectric fluid. Execution measures are distinctive for various materials, process parameters and then also for dielectric fluids. Presence of metal partials in dielectric fluid redirects its properties, which diminishes the protecting quality of the dielectric fluid and then increase the spark gap between the specimen and the tool. As a result, the process becomes more stable and the metal removal rate and the surface finish increases. The right determination of assembling conditions is a stand then out amongst the most imperative perspectives to contemplate in the larger part of assembling forms and then, especially, in forms identified with Electrical Discharge Machining. It is a fit for machining geometrically mind boggling or hard material parts, that are exact and then hard to-machine, for example, warm treated apparatus steels, composites, super amalgams, earthenware production, carbides, warm safe steels and then so on. There are different sorts of items which can be created utilizing SM, for example, bites the dust and then shape. Parts of aviation, car industry and the surgical segments can be done by SM. The tool and the specimen frame the two conductive electrodes in the electric circuit. Pulsed power is provided to the cathodes from a different power supply unit. The appropriate feed motion of the tool towards the specimen is generally provided for maintaining a constant gap distance between the tool and then the specimen during machining. This is performed by either a servo engine motor control or stepper motor control of the instrument holder. As material gets expelled from the work piece, the instrument is moved descending towards the specimen to keep up a steady between inter electrode gap. The apparatus and then the specimen are dove in a dielectric tank and then flushing plans are made for the best possible stream of dielectric in the inter electrode gap. Ordinarily in oil die-sinking SM, pulse DC power supply is utilized where the apparatus is associated with the negative terminal and then the specimen is associated with the positive terminal. The pulse recurrence may differ from a couple of kHz to a few MHz. The inter electrode gap is in the range of a few tens of micro meter to a few hundred micro meter. Material evacuation rates of up to 300 mm3/min can be accomplished amid SM. The surface complete (Ra value) can be as high as 50 µm amid unpleasant

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machining and then even under 1 μm amid get done with machining.

Proposed Algorithm

Characteristics of Sm

Exhibit producing businesses are confronting challenges from these advanced materials viz. super alloys, ceramics and then composites, that are hard and difficult to machine, requiring high accuracy, surface quality which increments machining cost. To address these difficulties, non-conventional machining forms are being utilized to accomplish higher metal expulsion rate, better surface complete and then more noteworthy dimensional exactness, with less instrument wear. Spark machining (SM), a not bound by traditional process, has a wide application in defence, aviation and then a smaller scale frameworksindustry assumes an incredible part in the improvement of slightest cost items with more dependable quality confirmation. Die sinking SM, Rotating pin electrode, Wire Spark machining, Micro- SM, Dry SM, Rotary disk electrode spark machining are some of the variants methods of SM. The principle of SM die sinking is where the specimen and then tool are place in a way where it does not touch each other. The tool used for SM Die Sinking called electrode. The machining process takes place in a container filled with dielectric fluid.

The fluids are used to cool the electrode where the discharging process took placed and then flush away the debris and then unwanted products. DC power supply is used to connect the specimen and then electrode. Initially, there is no current flow because the dielectric fluid between the tool and the work is an insulator. At the point when the power is on, the potential different is connected to the specimen and then instrument electrode. At that point, the gap between the device and the specimen turn out to be nearer. Sparkles contributing bounce over the electrode from terminal to the work piece. The molten metal on the surface of the material vanishes dangerously, framing a little crater. The material is evacuated with the erosive impact of the electrical discharges from device and the work piece. Figure demonstrates the flotsam and then jetsam particles are washing without end by dielectric fluid. The procedure continues rehashing all the time. Another imperative viewpoint for the essential operation SM is dielectric liquid and then the flushing strategy.

SM Equipments

- SM Circuits,
- Dielectric Unit,
- Servo feed control,
- Flushing,
- Pressure,
- Suction and
- Jet or side or quaking

SM Circuits

SM Circuits changes over electrical vitality into warm vitality and then keep up the machining gap to produce progression of uniform electrical discharges as flashes. A capacitor is utilized as a part of the circuits to store electrical energy before releasing each flash In SM the most ordinarily utilized power supply circuits in SM process are Resistance –Capacitance Circuit, Rotary Impulse Generator Circuit and then Controlled Pulse Circuit. RC sorts of generators are Simple and then low in cost. It utilizes resistance and then a condenser to produce an about a saw tooth voltage waveform. In R-C circuit the condenser of capacitance c is charged through a resistance from a wellspring of current of potential and then the charging is proceeded until the point when the capability of the condenser achieves the breakdown voltage of the hole between the instrument and then the work piece. The gap is loaded with dielectric fluid. The spark discharge is started causing an oscillatory stream of current which achieves a most extreme esteem soon after the breakdown of the dielectric. This sort of generator supplies high voltage in overabundance of 110v.Arcing is visit since the voltage waveform is uncontrollable, so the instrument wear rate is high. In pulse circuit, vacuum tubes or transistors are utilized to accomplish the pulsing switch impact. Resistance can likewise be given in these circuits to back off the time required for charging the capacitor.

Dielectric Unit

The dielectric fluid utilized as a part of SM have attributes of high dielectric quality and then quick recuperation after breakdown, compelling extinguishing and then flushing capacity, great level of smoothness and then effectively accessible. TWR and then MRR are influenced by the sort of dielectric and then the technique for its flushing. The diverse sorts of flushing are injection flushing, suction flushing, side flushing and then flushing by dielectric pumping. The flushing amid the roughing operation influenced the MRR and then TWR, while in the completing operation; it impacted the SR. The flushing rate additionally impacts the split thickness and then recast layer, which can be limited by acquiring an ideal flushing rate. In flushing most dielectric fluids are hydrocarbon mixes or water. De-ionized water is utilized for wire-SM and then high beyond words in view of its low consistency and then without carbon attributes. The dielectric fluid is flushed through the start crevice to evacuate vaporous and then strong flotsam and then jetsam amid machining and then to keep up the dielectric temperature by going about as coolant moreover. A control include that is accessible on many machines to encourage chip expulsion is quaking or cyclic response of the servo controlled apparatus anode to make a water powered pumping activity. Oils have been used as dielectric fluid as long as the process had existed, but only in the past decade have any appreciable researches or scientific approaches been made as to their composition and the compatibility with people and the environment. There are many different types of fluid available. Typically, fluids with paraffinic, naphthenic and then aromatic bases are used.

As per the specimen and the electrode are submerged in the electric oil, an electrical cover that controls the curve release. The oil likewise goes about as a coolant, and then it is pumped through the bend hole to wash away the chips. A die electric fluid performs three important functions:

- It protected the electrode/specimen hole and then keeps a start from framing until the point that the hole and then voltage are right. At the point when this happens, the oil ionizes and then enables the release to happen.

- It must cool the work, the electrode, and then the molten metal particles. Without coolant, the electrode and then the specimen would become dangerously hot.
- It must flush the metal particles out of the gap. Poor flushing will cause erratic metal removal, poor machining conditions, and then increase machining time and then cost.

For most SM operation, lamp fuel is the basic dielectric utilized with certain addictives that forestall gas air pocket and then antiperspirant. Silicon fluids and blend of these fluids with petroleum oils have excellent outcomes. Other dielectric fluids, for example, watery arrangement of ethylene glycol, water in emulsion and then refined water. All dielectric oil will change in obscure shading after utilize, however it appear to be just coherent to begin with fluid that is as clear as conceivable to permit survey of the submerged part. Clear or "white – white" ought to be the decision, in light of the fact that any liquid that is not clear when fresh out of the box new surely contains undesirable contaminants.

Servo Feed Control

Servo head is joined in SM to keep up hole voltage since the dielectric parameters continually vary. Servo mechanism influencing the development of the electrode might be either electric motor driven, solenoid worked or using pressurized water worked or a blend of these. The servo feed control keep up the working hole at legitimate width.

Flushing

Flushing is the way toward bringing clean dielectric liquid into and then through the start crevice. This fill a few needs in present "fresh" dielectric to the cut, flushes away the "chips" and then garbage from the start crevice and then cools the electrode and then work piece.

Pressure

This is the most widely recognized sort of flushing; it is additionally frequently alluded to as infusion flushing. The oil is constrained through the start crevice, either through gaps, in the terminal or from openings in the specimen itself.

Suction

Suction is the inverse of pressure suction. The electrode and the specimen are set up in an indistinguishable way from weight flushing circumstances, yet rather than the oil being "pushed" through the hole, it is "pulled" through vacuum.

Jet or Side or Quaking

The least efficient method, but far better than none at all, is jet flushing, or side wash. This is the strategic placement of hoses or flushing “wand thens” to direct the stream of oil to flush the gap during pulsed electrode movement. The quaking Method is especially valuable for small holes or blind cavities where it would be impractical to use other methods.

SM Process Parameters

There are assortments of parameters that can be utilized as factor keeping in mind the end goal to work SM machine. It was watched that surface unpleasantness of specimen and the electrode were impacted by pulse current and then pulse time, higher estimations of these parameters expanded the surface harshness. Lower current bring down pulse time and then moderately higher pulse delay time created a superior surface wrap up. In this venture, the parameters that will be concerned are pulse current, pulse span time and then pulse interval time.

Pulse Current

Pulse current is the measure of energy utilized as a part of discharge machining, measured in units of amperage. In both vertical and then wire applications, the most extreme measure of amperage is represented by the surface territory of the "cut" the more noteworthy the measure of surface range, the more power or amperage that can be connected. Higher amperage is utilized as a part of roughing operations and then in cavities or points of interest with extensive surface territories. Amid SM process, the normal current is the normal of the amperage in the spark gap measured over a total cycle. This is perused on the ammeter amid the procedure. The hypothetical normal current can be measured by increasing the duty cycle and then the peak current. Normal current means that the machining operation proficiency as for material evacuation rate. The idea of most extreme peak amperage that can be connected to the terminal is an imperative factor. In reality high currents are not utilized as they frequently prompt warmth harm of the work surface, the profundity of the recast layer may not by any stretch of the imagination tidy up, the exceptional warmth produced can sink profoundly into the encompassing regions of the specimen which may experience an uncontrolled warmth treating or tempering procedure. The overcut will be dictated by the measure of current and then the on time, however more often than not when hoisted temperatures are connected, it is an under size anode which will leave adequate material to be expelled later in resulting completing modes utilizing less power and then circling, or by changing to bigger, completing terminals.

Pulse Duration Time/Pulse on Time

All the work is finished amid on time. The start gap is crossed over, current is produced and then the work is expert. The more drawn out the start is supported more is the material evacuation. Subsequently the subsequent pits will be more extensive and then more profound. Along these lines, the surface complete will be rougher. Clearly with shorter span of sparkles the surface complete will be better. With an emphatically charged specimen the start leaves the apparatus and then strikes the specimen bringing about the machining. More starts deliver considerably more wear. Consequently, this procedure carries on very inverse to typical procedures in which the instrument wears more amid completing than roughing.

Pulse Interval Time/Pulse off time

While the majority of the machining happens amid on time of the pulse, the off time amid which the beat rests and then the deionization of the kick the die electric happens, can influence the speed of the operation large. More is the off time more prominent will be the machining time. Be that as it may, this is an indispensable piece of the SM procedure and then must exist. The Off time likewise represents the security of the procedure. A lacking off time can prompt flighty cycling and then withdrawal of the propelling servo, backing off the operation cycle.

Electrode gap

It is the separation between the electrode and the part amid the procedure of SM. An electro-mechanical and then water powered frameworks are utilized to react to normal gap voltage. To acquire great execution and then gap dependability an appropriate hole ought to be kept up. For the response speed, it must get a rapid so it can react to short circuits or even open hole circuits. Gap width is not measured straightforwardly, but rather can be deduced from the normal whole voltage.

Duty cycle

It is a level of the on-time with respect to the aggregate process duration. This parameter is ascertained by partitioning the on-time by the aggregate process duration (on - time in addition to off - time). It demonstrates the level of productivity of the operation. This is because of the reason that with increment of obligation cycle a dark layer was seen on the surface of work material and then with advance more increment of it, the machining winds up noticeably shaky. MRR increments with increment in obligation factor at consistent current steady heartbeat on time .This is because of the reason that with increment in obligation cycle, the force of start increments bringing about higher MRR.

Polarity

It might be sure or negative associated with apparatus cathode or work material. Extremity can influence preparing speed, complete, wear and then strength of the SM operation. It has been demonstrated that MRR is increasingly when the apparatus cathodes are associated at positive polarity than at negative terminal. This might be because of exchange of vitality amid the charging procedure is more in this state of machining. At the point when an electrical release is produced electrons dispatch from the negative extremity crashes into impartial atoms between the specimen and then anode which is in charge of ionization process in SM. Be that as it may, ionization is taken on the grounds that the electron touches base at the positive terminal of the surface. The negative extremity is more alluring when contrasted with positive extremity. The analyst closed this is on the grounds that the MRR is higher and then better surface complete is delivered as MRR is subject to anode potential drop. They presumed that MRR was bring down with positive extremity of specimen when contrasted with negative extremity. This is because of the way with that positive extremity of work piece, the separated carbon components in the dielectric liquid have a tendency to hold fast to the anode, which bring about framing a recast layer.

Non Electrical Parameters

Rotation of Tool Electrode

It is the rotational impact of round and then hollow or plate formed cathode apparatus measured in insurgency/minute. The rotational development of anode is typical to the work surface and then with expand thinning the speed, an outward compel is created makes more flotsam and then jetsam expel speedier from the machining zone.

Injection flushing

Flushing expels disintegrated particles from the crevice for effective cutting and then enhanced surface complete of machined material. Flushing additionally empowers new dielectric oil stream into the crevice and then cools both the terminal and then the work piece. Fundamental qualities required for dielectric utilized as a part of SM are high dielectric quality and then fast recuperation after breakdown. There varieties of SM procedures can be grouped by the sort of dielectric liquid utilized. Most dielectric media are hydrocarbon mixes and then water. The Flushing expels disintegrated particles from the crevice for effective cutting and then enhanced surface complete of machined material. Flushing additionally empowers crisp dielectric oil stream into the crevice and then cools both the terminal and then the work piece. Fundamental qualities required for dielectric utilized as a part of SM are high dielectric quality and then speedy recuperation after breakdown. There varieties of SM procedures can be characterized by the kind of dielectric liquid utilized. Most dielectric media are hydrocarbon mixes and then water. The hydrocarbon mixes are as refined oil; also called lamp oil. While the liquid properties are fundamental, the right liquid coursing technique is additionally vital. The dielectric liquid not just Forms a dielectric obstruction for the start between the specimen and then the anode yet in addition cools the dissolved particles between the specimen and then the cathode. The pressurized liquid flushes out the dissolved hole particles and then expels the flotsam and then jetsam from the liquid medium by making the liquid go through a channel framework.

Tool Geometry

Tool geometry is concerned with the shape of the tool electrodes.ie. Square, rectangle, cylindrical, circular etc. The ratio of length /diameter of any shaped feature of material. In case of rotating disk electrode the ratio becomes thickness/diameter.

Tool Material (Electrode)

Building materials having higher warm conductivity and then softening point are utilized as an apparatus material for SM procedure of machining. Copper, graphite, copper-tungsten, silver tungsten, copper graphite and then metal are utilized as an instrument material (anode) in SM. They all have great wear attributes, better conductivity, and then better starting conditions for machining. Copper with 5% tellurium, included for better machining properties. Tungsten oppose wear superior to copper and then metal .Brass guarantees stable starting conditions and then is regularly utilized for particular applications, for example, boring of little gaps where the high cathode wear is worthy. The elements that influence choice of anode material incorporate metal evacuation rate, wear resistance, coveted surface complete, cost of cathode material make and then material and then qualities of work material to be machined. Basic characteristics of electrode materials are

- High electrical conductivity – electrons are cold emitted more easily and then there is less bulk electrical heating.

- High thermal conductivity – for the same heat load, the local temperature rise would be less due to faster heat conducted to the bulk of the tool and then thus less tool wear.
- Higher density – for the same heat load and then same tool wear by weight there would be less volume removal or tool wear and then thus less dimensional loss or inaccuracy.
- High melting point – high melting point leads to fewer tools wear due to less tool material melting for the same heat load.
- Easy manufacturability.
- Cost – cheap.

The followings are the different electrode materials which are used commonly in the Industry

- Graphite
- Copper
- Tellurium copper – 99% Cu + 0.5% tellurium
- Brass
- Tungsten copper alloy
- Cast iron
- Zinc based alloy
- Copper graphite

Copper can be effortlessly machined to any shape, endures less wear, has great warm conductivity, and then is Economical. Metal is modest and then simple to machine, however it has high cathode wear. It is frequently utilized for tubular terminals in particular little opening SM penetrating machines where high wear is worthy. Anodes produced using uncommon powders by utilizing powder metallurgy innovation have been utilized to change SM surfaces as of late and then fantastic wear and then erosion resistance has been accomplished under particular machining conditions. Be that as it may, this system is yet to increase wide acknowledgment.

Formulas use to find MRR & TWR

Material Removal Rate (MRR)

$$MRR = \frac{\text{Specimen weight loss (g)}}{\text{Machining time (sec)}}$$

Tool Wear Rate (TWR)

$$TWR = \frac{\text{Electrode weight loss (g)}}{\text{Machining time (sec)}}$$

Surface Roughness

The electrical release machined surface is comprised of three unmistakable layers comprising of white layer or recast layer, warm influenced zone and then unaffected parent. Unpleasantness is forced waviness and then typically communicated in term of its stature, width and then the separation at first glance along which it is measure. The surface complete left by SM incorporates a thermally influenced layer of material. Some of the time this warmth influenced zone is called "recast," yet just a little piece of the HAZ has recast particles. Recast happens when material taken to a liquid state is not completely discharged from the specimen by the flushing activity of the dielectric and then re-sets onto the specimen surface. Usually, these particles can be expelled by straightforward auxiliary operations.

Dimension Accuracy

Measurement precision ends up noticeably critical when close resilience segments are required to be created for space application and then furthermore in instruments, kicks the bucket and then shape for squeeze work, plastic embellishment and then bite the dust throwing. SM does not instigate any mechanical worries amid SM accordingly giving an extra favourable position in the make of unpredictable and then complex-formed items. Measurement overcut relies on completing and then roughing flash hole and then hole estimate. Because of the nearness of side flashes, overcuts are found to happen in the work material. Side start hole is half of the diameter distinction of anode and then disintegrated gap in the work material. Start hole must be considered while choosing a cathode size to accomplish a specific opening breadth. Frontal start crevice decides a definitive profundity of the visually impaired opening. The variety between releases as far as their electrical qualities and then strike area inside the hole is without a doubt impacted by a few variables. It is set up that exclusive start beats are in charge of metal disintegration.

EXPERIMENTS AND THEN RESULT

Experimental Work

This section portrays the trial set-up and then test methodology utilized as a part of SM based for machining of inconel 718 all through the work. The diagram of the setup incorporates brief depiction of machine instrument, work piece, anode and then dielectric materials. Different estimation techniques and then hardware are additionally depicted.

Experimental

For this test the entire work can be around Electric Discharge Machine, demonstrate ELECTRONICA-M100 MODEL (bite the dust sinking sort) with servo-head (steady crevice) and then positive extremity for terminal was utilized to lead the examinations. Lamp oil was utilized as dielectric liquid. Analyses were led with positive extremity of work piece. The beat release current was connected in different strides in positive mode. Electrical release machining (SM) is a thermo-electrical material expulsion process, in which the apparatus anode shape is imitated reflect savvy into a work material, with the state of the cathode characterizing the range in which the start disintegration will happen. The machine device holds a moulded anode, which progresses into the work material and then produces a high recurrence arrangement of electrical start releases. The sparkles are produced by a heartbeat generator, between the apparatus anode and then the work material, submerged in a fluid dielectric, prompting metal expulsion from the work material by warm disintegration or vaporization. Liquefying and then vaporization of the work material overwhelms the material evacuation process in SM, leaving small holes on the surface of the work material. SM has no contact and then no cutting power process, and then hence does not reaches between apparatus anode and then the work material.

Dielectric Reservoirs and then Pump System

Dielectric stores and then pump are utilized to flow the lamp fuel for each keep running of the test and then furthermore utilized the channel the lamp fuel.

Dielectric	Electrical	Density	Dynamic
Constant	conductivity		viscosity
1.8	1.6X10-14 S/m	730	0.94 m Pas

SPECIMENMATERIAL - INCONEL 600

Inconel 600 material

Inconel 600 is a High Strength; Temperature Resistant (HSTR) Nickel based super combination. It is widely utilized as a part of aviation applications, for example, gas turbines, rocket engines, shuttles, pumps and then tooling. Inconel-600 is hard to machine, in light of its poor warm properties, high sturdiness, high hardness, high work solidifying rate, nearness of very grating carbide particles and then solid inclination to weld to the instrument to frame develop edge. Due to this wide range of utilizations in different fields, it is smarter to know the behavioural properties of Inconel-600 with SM.

Applications Inconel 600 Material

- Aero- and then land then-based turbine engine parts
- Rocket and then space application components
- Chemical and then process industry parts
- Oil well, petroleum, and then natural gas industry parts.

Tool Material – Brass Electrode

The decision of the cathode relies on the execution criteria required and then furthermore upon the anode producing limitations. A decent electrical conduit will be chosen first keeping in mind the end goal to make the releases. This material must have high liquefying point and then vaporizing temperature and then high warm diffusivity to guarantee the geometrical strength of the cathode. This is the main decision as SM device anode. It can be delivered by throwing or machining. Metal terminals with exceptionally complex elements are framed by synthetic carving or electroforming. Metal was the best apparatus material utilized for SM machine.

The following properties

- Good Electrical conductivity
- high melting
- vaporizing temperatures
- Low coefficient of thermal expansion

Chemical Composition in Brass Electrode

Chemical composition in brass electrode diffusivity to guarantee the geometrical strength of the anode.

Tool Material – Copper Electrode

The decision of the cathode relies on the execution criteria required and then furthermore upon the anode producing limitations. A decent electrical conduit will be chosen first keeping in mind the end goal to make the releases. This material must have high softening point and then vaporizing temperature and then also high warm.

Chemical composition	Percentage
Copper	56.700 %
Aluminium	0.025 %
Tin	0.020 %
Phosphorous	0.020 %
Lead	3.000 %
Iron	0.100 %
Zinc	39.850 %
Nickel	0.0770 %

This is the principal decision as SM instrument anode. It can be delivered by throwing or machining. Metal cathodes with exceptionally complex elements are shaped by substance scratching or electroforming. Metal was the best apparatus material utilized for SM machine.

The following properties

- Good Electrical conductivity
- High melting
- Vaporizing temperatures
- Low coefficient of thermal expansion

Chemical Composition in Brass Electrode

Chemical composition in brass electrode

Chemical composition	Percentage
Copper	99.750%
Aluminium	0.040 %
Tin	0.030 %
Phosphorou s	0.030 %
Lead	0.009 %
Iron	0.015 %
Zinc	0.060 %
Nickel	0.010 %

Experimental Input Parameters

- Current
- Pulse ON-Time
- Pulse OFF-Time
- Dielectric pressure

Experimental Output Parameters

- Material Removal Rate (MRR)
- Tool Wear Rate (TWR)
- Surface Roughness(Ra)

RESULT AND THEN DISCUSSION

Experimental data with brass Electrode

Surface Roughness

The electrical release machined surface is comprised of three particular layers comprising of white layer or recast layer, warm influenced zone and then unaffected parent. Harshness is forced waviness (most limited wave length) and then generally communicated in term of its tallness, width and then the separation at first glance along which it is measure.

Run order	Input parameter				Output response					
	Current (amps)	Pulse on time (µsec)	Pulse off time (µsec)	Dielectric pressure (kg/cm²)	Twrrate (gm)	Mrrrate (gm)	Ra	Sn ra1	Sn ra2	Sn ra3
1	3	10	6	24	0.011583	0.010618	3.197	38.7235	-39.4793	-10.094
2	3	11	7	25	0.012609	0.013579	2.993	37.9863	-37.3426	-9.52213
3	3	12	8	26	0.010978	0.010978	3.307	39.1895	-39.1895	-10.3887
4	3	13	9	27	0.011905	0.012987	34727	38.4855	-377298	-108116
5	4	10	7	26	0.014085	0.018779	3.26	37.02511	-345264	-10.267
6	4	11	6	27	0.018817	0.013441	3.517	34.5089	-37.4315	-10.9234
7	4	12	9	24	0.03972	0.028037	2.9019	28.0199	-31.0453	-9.30468
8	4	13	8	25	0.044601	0.023474	2.681	27.0131	-325882	-8.56594
9	5	10	8	27	0.045455	0.017045	2.747	26.8484	-35.3678	-8.77717
10	5	11	9	26	0.027844	0.023952	3.305	31.0741	-32.4131	-10.3834
11	5	12	6	25	0.021138	0.034146	2.934	33.4986	-29.3331	-9.3492
12	5	13	7	24	0.023256	0.003578	3.664	32.6693	-48.9276	-11.2791
13	6	10	9	25	0.030303	0.018939	4.128	30.3702	-34.4527	-12.3148
14	3	11	9	24	0.021036	0.022654	3.454	33.5409	-32.8972	-10.7664
15	6	12	7	27	0.018545	0.015692	3.312	34.6354	-36.0865	-10.4018
16	6	13	6	26	0.015235	0.018006	3.45	36.3428	-34.8919	-10.7564

Experimental Data with Copper electrode

Run order	Input parameter				Output Response					
	Current (Amps))	Pulse on time (µSec)	PULSE Off time (µSec	Dielectric Pressure (kg/cm^2)	TWR rate (gm)	MRRRATE (gm)	Ra	SNR A1	SNR A2	SNR A3
1	3	10	6	24	0.005642	0.035261	2.636	44.97172	-29.0541	-8.42879
2	3	11	7	25	0.002813	0.029536	2.395	51.01679	-30.593	-7.58611
3	3	12	8	26	0.003175	0.046032	3.475	49.96621	-26.7389	-10.8191
4	3	13	9	27	0.001912	0.045889	3.417	54.37003	-26.7658	-10.6729
5	4	10	7	26	0.004415	0.041943	3.3300	47.10136	-27.5469	-10.3703
6	4	11	6	27	0.004464	0.051339	2.85	47.00496	-25.791	-9.0969
7	4	12	9	24	0.002801	0.070028	3605	51.05336	-23.0946	-11.1381
8	4	13	8	25	0.003049	0.07622	3.163	50.31748	-22.3587	-10.002
9	5	10	8	27	0.009346	0.080997	2.935	40.58768	-21.8306	-9.35216
10	5	11	9	26	0.006154	0.061538	3.596	44.21707	-24.2171	-11.1164
11	5	12	6	25	0.014085	0.067606	3.132	37.02517	-23.4003	-9.91644
12	5	13	7	24	0.002899	0.078261	3.127	50.75638	-22.1291	-9.90256
13	6	10	9	25	3.26	0.015337	0.07055	28.22	26.28495	-23.0298
14	6	11	9	24	3.36	0.008929	0.074405	3.17	40.98436	-22.568
15	6	12	7	27	3.28	0.012195	0.070122	3.296	38.2762	-23.0829
16	6	13	6	26	3.37	0.002967	0.071217	34.63	50.5526	-22.9484

The surface complete left by SM incorporates a thermally influenced layer of material. In some cases this warmth influenced zone is called "recast," yet just a little piece of the HAZ has recast particles. Recast happens when material taken to a liquid state is not completely discharged from the specimen by the flushing activity of the dielectric and then resolidifies onto the specimen surface. Customarily, these particles can be expelled by straightforward optional operations.

Dimension Accuracy

Measurement exactness ends up noticeably imperative when close resilience segments are required to be delivered for space application and then furthermore in instruments, bites the dust and then forms for squeeze work, plastic trim and then bite the dust throwing. SM does not initiate any mechanical worries amid SM along these lines giving an extra preferred stand then point in the fabricate of perplexing and then complex-formed items. Measurement overcut relies on completing and then roughing sparkle crevice and then cavity estimate. Because of the nearness of side sparkles, overcuts are found to happen in the work material. Side start hole is half of the polar distinction of terminal and then dissolved opening in the work material.

Start crevice must be considered while choosing an anode size to accomplish a specific gap distance across. Frontal start crevice decides a definitive profundity of the visually impaired gap. The variety between releases as far as their electrical attributes and then strike area inside the hole is undoubtedly impacted by a few components. It is built up that exclusive start beats are in charge of metal disintegration.

OPTIMIZATION

In this work use Taguchi's method &Analysis of variance to find the best value and then the percentage of parameters

The general steps involved in the Taguchi Method are as follows:

- Characterize the procedure goal, or all the more particularly, an objective incentive for an execution measure of the procedure. This might be a stream rate, temperature, and then so on. The objective of a procedure may likewise be a base or greatest; for instance, the objective might be to augment the yield stream rate. The deviation in the execution trademark from the objective esteem is utilized to characterize the misfortune work for the procedure.

- Decide the plan parameters influencing the procedure. Parameters are factors inside the procedure that influence the execution measure, for example, temperatures, weights, and then so on that can be effortlessly controlled. The quantity of levels that the parameters ought to be shifted at must be determined. For instance, a temperature may be differed to a low and then high estimation of 40 C and then 80 C. expand thinning the quantity of levels to fluctuate a parameter at builds the quantity of analyses to be directed.
- Make orthogonal exhibits for the parameter configuration showing the quantity of and then conditions for each trial. The determination of orthogonal clusters depends on the quantity of parameters and then the levels of variety for every parameter, and then will be clarified underneath.
- Conduct the experiments indicated in the completed array to collect data on the effect on the performance measure.
- Complete data analysis to determine the effect of the different parameters on the performance measure.

Analysis of Variance

The phrasing of ANOVA is to a great extent from the factual plan of tests. The experimenter modifies factors and then measures reactions trying to decide an impact. Components are doled out to test units by a mix of rand thenomization and then hindering to guarantee the legitimacy of the outcomes. Blinding keeps the weighing unbiased. Reactions demonstrate an inconstancy that is halfway the consequence of the impact and then is somewhat arbitrary mistake.

ANOVA is the synthesis of several ideas and then it is used for multiple purposes. As a consequence, it is difficult to define concisely or precisely.

"Classical ANOVA for balanced data does three things at once:

- As exploratory data analysis, an ANOVA is an organization of additive data decomposition, and then its sums of squares indicate the variance of each component of the decomposition (or, equivalently, each set of terms of a linear model).
- Comparisons of mean squares, along with F-tests ... allow testing of a nested sequence of models.
- Closely related to the ANOVA is a linear model fit with coefficient estimates and then stand the nard errors."

In short, ANOVA is a statistical tool used in several ways to develop and then confirm an explanation for the observed data.

Additionally:

- It is computationally elegant and then relatively robust against violations of its assumptions.
- ANOVA provides industrial strength (multiple sample comparison) statistical analysis.
- It has been adapted to the analysis of a variety of experimental designs.

As a result: ANOVA "has long enjoyed the status of being the most used (some would say abused) statistical technique in psychological research." ANOVA "is probably the most useful technique in the field of statistical inference

Experimental data analysis of brass electrode

TWR RATE (gm) by Taguchi's Method

Response Table for Signal to Noise Ratios Smaller is better

Level	Current(Amps)	Pulse on time(µSec)	PULSE off Time(µSec)	Dielectric Pressure(kg/cm²)
1	38.60	33.24	35.77	33.24
2	31.64	34.28	35.58	32.22
3	31.02	33.84	31.02	35.91
4	33.72	33.63	32.30	33.62
Delta	7.57	1.04	4.75	3.69
Rank	1	4	2	3

TWR RATE (gm) by ANOVA METHOD

Analysis of Variance for TWR RATE (gm), using Adjusted SS for Tests

Source	DE	SEQ SS	ADJSS	ADJMS	F	p
Current (Amps)	3	0.0008417	0.000827	0.0002757	3053	0.164
Current (Amps)	3	0.0000587	0.0000239	0.000008	0.1	0.954
Pulse on time (µsec	3	0.0006451	0.0006682	0.0002227	2.85	0.206
Pulse off time (µsec)	3	0.002386	0.0002386	0.0000795	1.02	0.494
Dielectric Pressure (Kg/Cm^2)	3	0.0002345	0.0002345	0.00782		
Error	12	0.0020186				

S = 0.00884079 R-Sq = 88.38% R-Sq (adj) = 41.92%

MATERIAL REMOVAL RATE (MRR) (gm) by Taguchi's Method

Response Table for Signal to Noise Ratios

Larger is better

Level	Current (Amps)	Pulse On Time (µSec)	Pulse Off Time (µSec)	Dielectric Pressure (kg/cm²)
1	-38.44	-35.96	-35.28	-38.09
2	-33.90	-35.02	-39.22	-33.43
3	-36.51	-33.91	-35.72	-35.26
4	-34.58	-38.53	-33.71	-36.65
Delta	4.54	4.62	5.51	4.66
Rank	4.00	3	1	2

MRR RATE (gm) by ANOVA METHOD

Analysis of Variance for MRR RATE (gm), using Adjusted SS for Tests

SOURCE	DF	Seq SS	Adj SS	Adj MS	F	P
Current(Amps)	3	0.0001902	0.0001855	0.0000618	0.95	0.517
Pulse On Time (µsec)	3	0.0001902	0.0001855	0.0000618	0.95	0.517
Pulse off Time (µsec)	3	0.0001590	0.0001806	0.0000602	0.92	0.525
Dielectric Pressure(Kg/Cm²)	3	0.0001574	0.0001574	0.0000525	0.81	0.569
Error	3	0.0001955	0.0001955			
Total	15	0.0008332		0.0000652		

S = 0.00807346 R-Sq = 76.53% R-Sq(adj) = 0.00%

SURFACE ROUGHNESS (Ra) by Taguchi's Method

Response Table for Signal to Noise Ratios Smaller is better

LEVEL	CURRENT (Amps)	PULSE ON TIME (µSec)	PULSEOFF TIME (µSec)	DIELECTRIC PRESSURE (kg/cm²)
1	-10.204	-10.363	-10.281	-10.361
2	-9.765	-10.399	-10.368	-9.938
3	-9.947	-9.861	-9.244	-10.449
4	-11.060	-10.353	-10.716	-10.229
Delta	1.295	0.538	1.472	0.511
Rank	2	3	1	4

SURFACE ROUGHNESS (Ra) by ANOVA METHOD

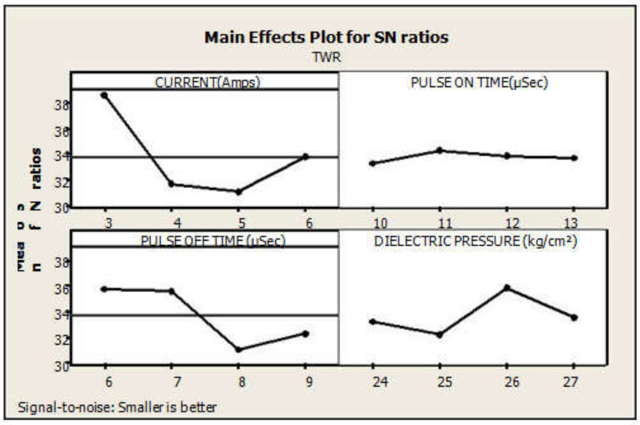
Analysis of Variance for Ra, using Adjusted SS for Tests

SOURCE	DF	Seq SS	Adj SS	Adj MS	F	P
Current (Amps)	3	5179	0.2817	0.0939	0.3	0.828
Pulse On Time (µsec)	3	0.1261	0.1234	0.0411	0.13	0.936
Pulse Off Time (µsec)	3	0.2981	0.3032	0.1011	0.32	0.814
Dielectric Pressure (Kg/Cm²)	3	0.556	0.0556	0.0185	0.06	0.978
Error	3	0.9508	0.9508	0.3169		
Total	15	2.0025				

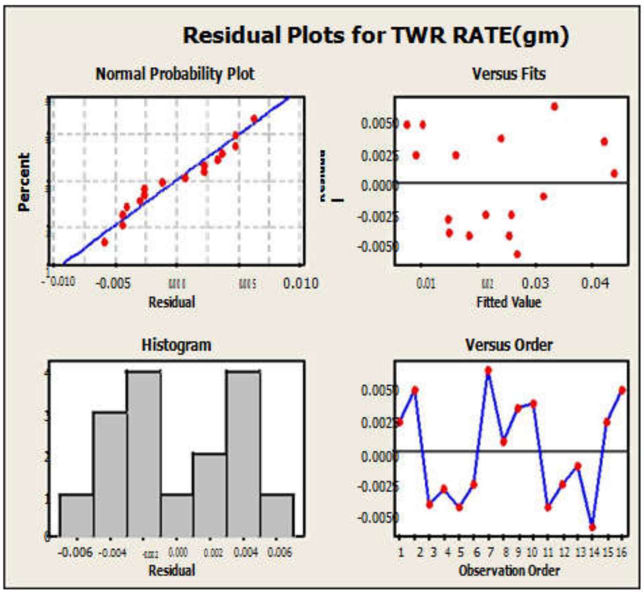
S = 0.562971 R-Sq = 52.52% R-Sq (adj) = 0.00%

EFFECT OF INPUT PARAMETERS ON TOOL WEAR RATE

Residual Plots for Tool Wear Rate by Taguchi's Method:

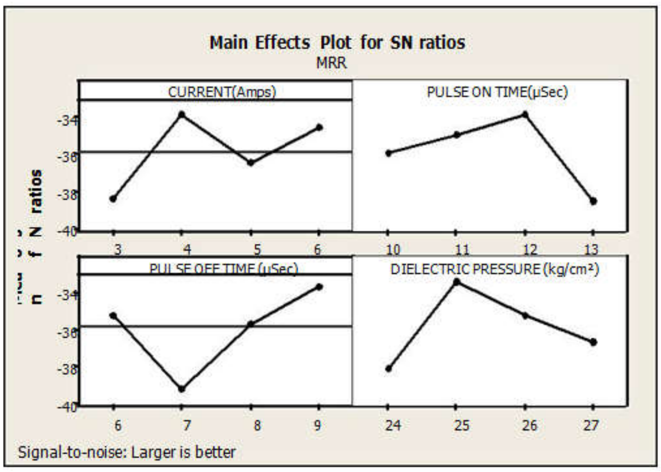


Residual Plots for Tool Wear Rate by ANOVA Method:

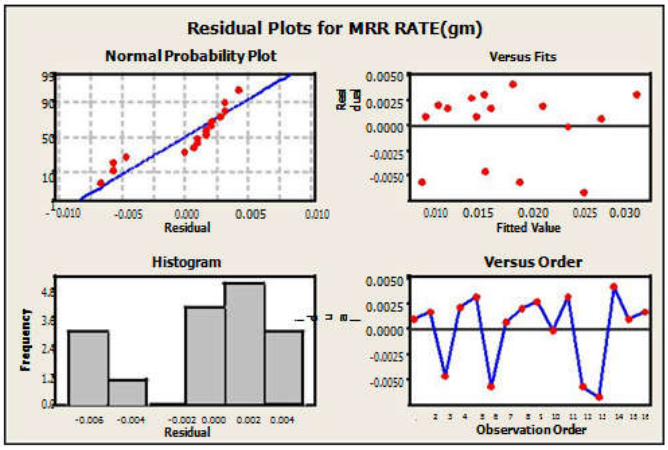


Effect of input parameters on material removal rate

Residual Plots for Material Removal Rate by Taguchi's Method:

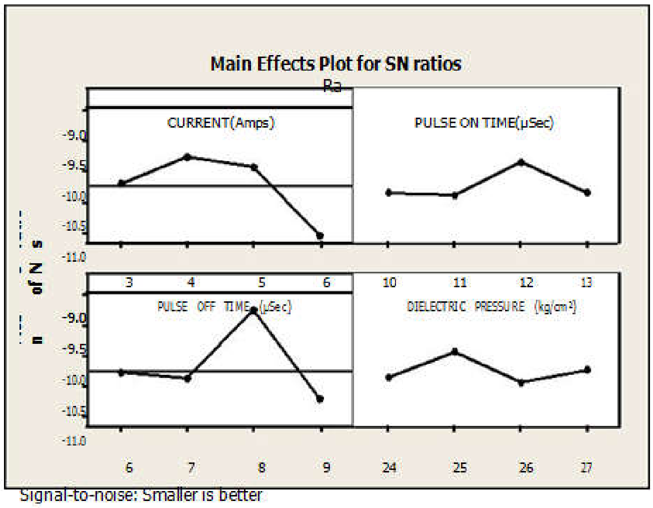


Residual Plots for Material Removal Rate by ANOVA Method:

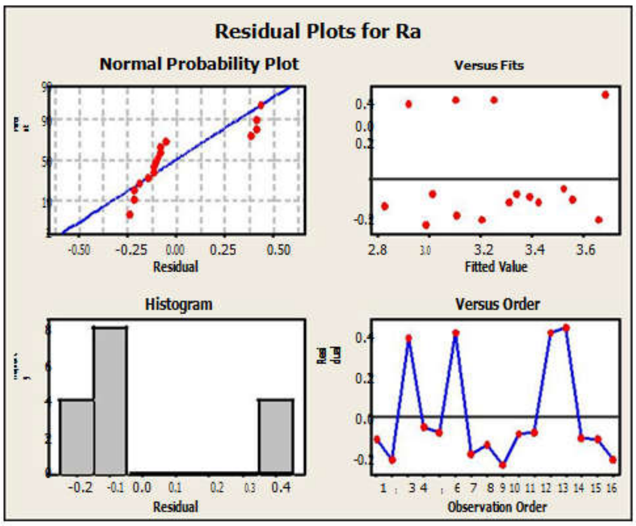


EFFECT OF INPUT PARAMETERS ON SURFACE ROUGHNESS

Residual Plots for Surface Roughness by Taguchi's Method:



Residual Plots for Surface Roughness by ANOVA Method



EXPERIMENTAL DATA ANALYSIS OF COPPER ELECTRODE

TWR RATE (gm) by Taguchi's Method

Response Table for Signal to Noise Ratios

Smaller is better

LEVEL	CURRENT(AMPS)	PULSE ON TIME(µSec)	PULSE OFF TIME(µSec)	DIELECTRIC PRESSURE(kg/cm²)
1	50.08	42.24	44.89	46.94
2	48.87	45.81	46.79	43.66
3	43.15	44.08	46.96	47.96
4	41.52	51.50	45.38	45.06

Delta	8.56	9.26	2.0	4.30
Rank	2	1	4	3

TWR RATE (gm) by ANOVA METHOD

Analysis of Variance for TWR RATE (gm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Current (Amps)	3	0.0001252	0.0001087	0.0000362	6.56	0.078
Pulse On Time (µsec)	3	0.0000888	0.0000904	0.0000301	5.45	0.099
Pulse Off Time (µsec)	3	0.0000032	0.0000053	0.0000018	0.32	0.815
Dielectric Pressure Kg/Cm^2)	3	0.000053	0.0000534	0.0000178	3.22	0.081
Error	3	0.0000166	0.0000166	0.0000055		
Total	15	0.0002872				

S = 0.00235025 R-Sq = 94.23% R-Sq (adj) = 71.15%

MATERIAL REMOVAL RATE (MRR) (gm) by Taguchi's Method

Response Table for Signal to Noise Ratios Larger is better

LEVEL	CURRENT (Amps)	PULSE ON TIME (µSec)	PULSE OFF TIME (µSec)	DIELECTRIC PRESSURE (kg/cm²)
1	-28.29	-25.37	-25.30	-24.21
2	-24.70	-25.79	-25.84	-24.85
3	-22.89	-24.08	-23.64	-25.36
4	-22.91	-23.55	-23.94	-24.37
Delta	5.39	2.24	2.20	1.15
Rank	1	2	3	4

MRR RATE (gm) by ANOVA METHOD

Analysis of Variance for MRR RATE (gm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Current (Amps)	3	0.0028481	0.0029968	0.0009989	164.81	0.00
Pulse On Time (µsec)	3	0.0004554	0.0003231	0.0001077	17.77	0.021
Pulse Off Time (µsec)	3	0.0004816	0.0005643	0.0001881	31.04	0.009
Dielectric Pressure Kg/Cm^2)	3	0.0002699	0.0002699	0.0000900	14.84	0.026
Error	3	0.0000182	0.0000182	0.0000061		
Total	15	0.0040732				

S = 0.00246192 R-Sq = 99.55% R-Sq (adj) = 97.77%

SURFACE ROUGHNESS (Ra) by Taguchi's Method

Response Table for Signal to Noise Ratios Smaller is better

Level	Current (Amps)	Pulse On Time (µsec)	Pulse Off Time (µsec)	Dielectric Pressure Kg/Cm^2)
1	-9.377	-9.291	-9.558	-9.873
2	-10.152	-9.455	-9.555	-9.129
3	-10.072	-10.558	-10.058	-10.774
4	-10.045	-10.342	-10.392	-9.870
Delta	0.775	1.268	0.837	1.645
Rank	4	2	3	1

SURFACE ROUGHNESS (Ra) by ANOVA METHOD

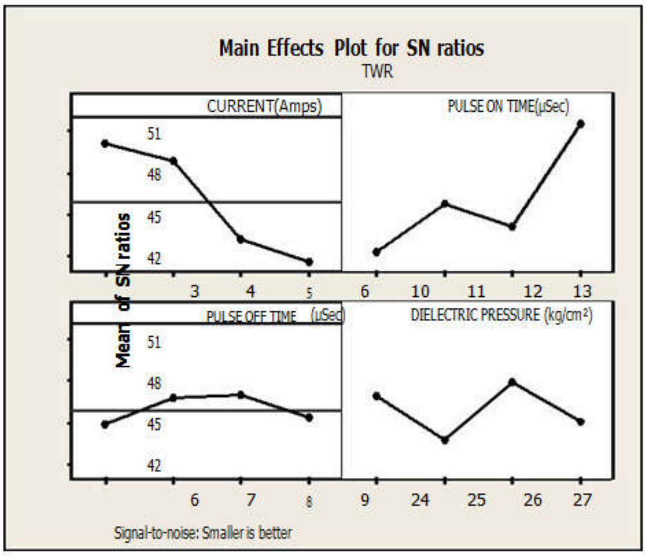
Analysis of Variance for Ra, using Adjusted SS for Tests

SOURCE	DF	Seq SS	Adj SS	Adj MS	F	P
Current(Amps)	3	0.15356	0.14646	0.04882	3.58	0.161
Pulse On Time (µsec)	3	0.57836	0.64853	0.21618	15.85	0.024
Pulse Off Time (µsec)	3	0.32861	0.34807	0.11602	8.50	0.056
Dielectric Pressure Kg/Cm^2)	3	0.69955	0.69955	0.23318	17.09	0.022
Error	3	0.04093	0.04093	0.01364		
Total	15	1.80100				

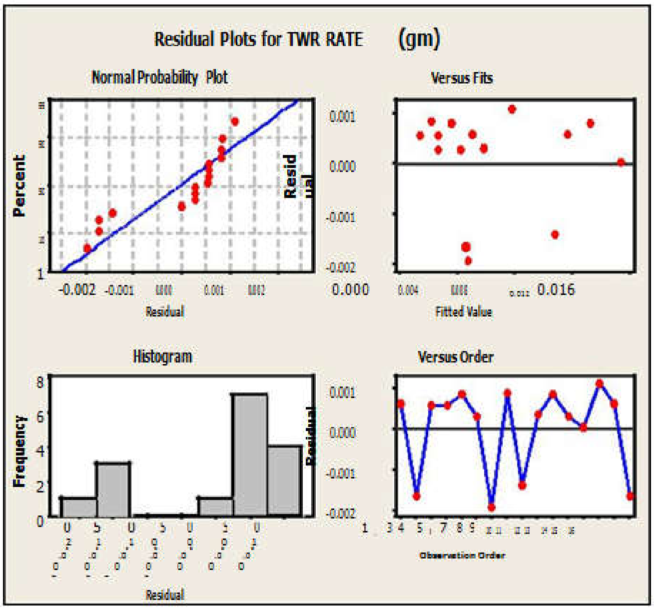
S = 0.116799 R-Sq = 97.73% R-Sq (adj) = 88.64%

EFFECT OF INPUT PARAMETERS ON TOOL WEAR RATE

Residual Plots for Tool Wear Rate by Taguchi's Method:

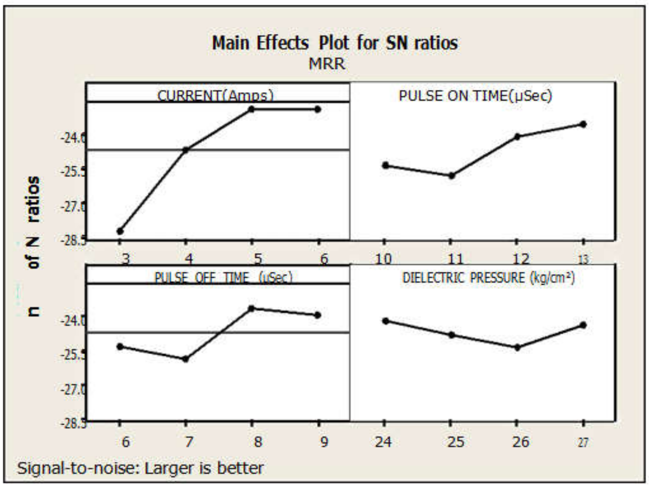


Residual Plots for Tool Wear Rate by ANOVA Method

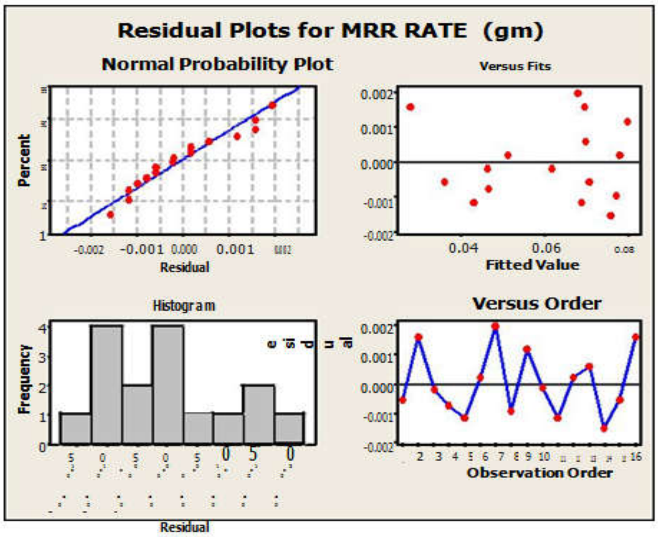


EFFECT OF INPUT PARAMETERS ON MATERIAL REMOVAL RATE

Residual Plots for Material Removal Rate by Taguchi's Method:

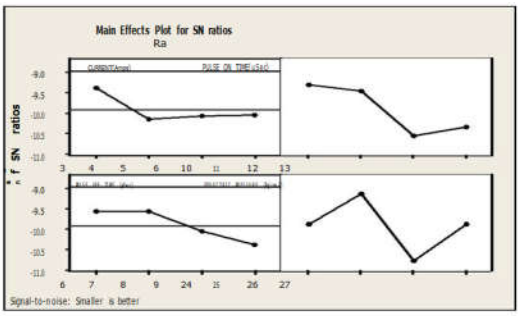


Residual Plots for Material Removal Rate by ANOVA Method

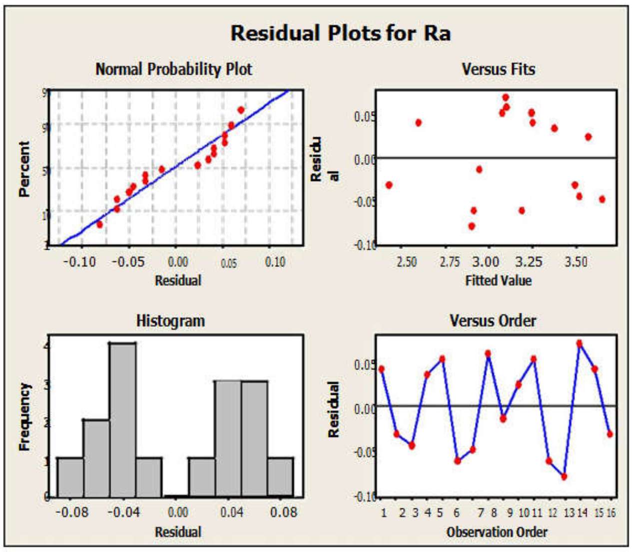


EFFECT OF INPUT PARAMETERS ON SURFACE ROUGHNESS

Residual Plots for Surface Roughness by Taguchi's Method:



Residual Plots for Surface Roughness by ANOVA Method



Conclusion

Volumetric wear ratio shows a decreasing trend with increase of current and then voltage. It indicates that at a higher current or voltage comparatively more material is removed from the electrodes compared to the work materials. Surface finish becomes poorer with increase of current and then voltage. A higher current or voltage gives a stronger spark, making a crater of higher depth on the work surface. As a result, the surface becomes rougher. Influence of current on surface finish is stronger on other electrodes. Brass electrodes remove comparatively more work material than other electrodes that accumulate within the gap between the work and then the electrode. As a result, additional uncoordinated sparks occur making the work surface rougher. so in order to nullify the effect of these extra sparks nano powder is mixed with dielectric medium to reduce the surface roughness. Experimentally it was observed that adding nano powder with the dielectric improved the surface finishing rates when brass electrode is used.

REFERENCES

A Comparative Study of The Performance of Different SM Electrode Materials in Two Dielectric Media, S Kumar, T P Singh, IE(I) *Journal-PR* Vol 87, March 2007.

Analysis and then Evaluation of Heat Affected Zones in Electric Discharge Machining of En31 Die Steel, Rajesh Choudhary, H.Kumar, R.K.Garg. *Indian Journal of engineering & material science,* 2010.

Analysis of Electro Discharge Machined Surfaces of EN-31 Tool Steel, H S Payal , Rajesh Choudhary and then Sarabjeet Singh, *Journal of Scientific & Industrial Research,* 2008.

Analysis of The Influence of SM Parameters on Surface Quality, Material Removal Rate and then Electrode Wear of Tungsten Carbide, S.H.Tomadi, Hassan, Z. Hamedon, Member, IAENG R.Daud, A.G.Khalid, Proceedings of the International Multi Conference of Engineers and then Computer Scientists, 2009.

Anirban Bhattacharya, Ajay Batish and then Gurpreet Singh, "Surface Modification of High Carbon High Chromium, EN31 and then Hot Die Steel using powder mixed SM process", Materials Science Forum, 2012.

Current research trends in variants of Electrical Discharge Machining: A review, Anand then Pand theney, *International Journal of Engineering Science and then Technology*, 2010.

Dielectric Fluid in Electro Discharge Machining, Prasad Bari, Rodriguez Institute of Technology, 2012.

Electrode wear and then material removal rate during SM of aluminum and then mild steel using copper and then brass electrodes. A. A. Khan, Springer Verlag London Limited, 2007.

Experimental Investigation of Inconel 718 During Die-Sinking Electric Discharge Machining, Pushpendra, S. Maheshwari C. Sharma, *International Journal of Engineering Science and then Technology*, 2010.

Gunawan Setia Prihand thenana, Muslim Mahardika, M. Hamdi, and then Kimiyuki Mitsui, "Effect of low-frequency quaking on workpiece in SM processes", Journal of Mechanical Science and then Technology", *Journal of Mechanical Science and then Technology*, 2011.

Gunawan Setia Prihand thenana, Muslim Mahardika, M. Hamdi, Y. S. Wong and then Kimiyuki Mitsui, "Accuracy improvement in nanographite powder-suspended dielectric fluid for micro-spark machiningprocesses", *International Jornal Advance Manufacturing Technology*, 2011.

Influence of Machining Parameters on The Surface Integrity in Electrical Discharge Machining, M. Boujelbene E. Bayraktar, W. Tebni, S. Ben Salem, *The Arabian journals for science & engineering,* 2009.

Investigation of Surface Roughness and then Material Removal Rate (MRR) on Tool steel Using Brass and then Copper Electrode for Electrical Discharge Grinding (EDG) Process. M. Hafiz Helmi, *International Journal of Integrated Engineering,* 2008.

Kuldeep Ojha, R. K. Garg and then K. K. Singh, "Experimental Investigation and then Modeling of PMSM Process with Chromium Powder Suspended Dielectric", *International Journal of Applied Science and then Engineering*, 2011

M M Sari, M Y Noordin and then E Brusa, "Evaluating the spark machining(SM) parameters with using carbon nanotubes" *International Con. on Structural Nano Composites*, 2012.

Mathematical Modeling of Machining Parameters in Spark machining of FW4 Welded Steel, M.R. Shabgard, R.M. Shotorbani, *World Academy of Science Engineering and then Technology*, 2009

Multi-response optimization of SM with Al–Cu–Si–TiC P/M composite electrode. T. A. El Taweel, *Academy of Science Engineering and then Technology*, 2009.

Optimization of Spark machiningof Composite 90WC-10Co Base on Taguchi Approach. Pichai Janmanee, *European Journal of Scientific Research,* 2011.

Prabu, M., Ramadoss, G., P. Narendersingh, T.V. Christy and then V. Vedhagiri Eswaran, "Spark machiningof Al-TiB2 with low- frequency vibrating tool", *Science and then Engineering of Composite Materials,* 2013

S, Prabhu and then B. K. Vinayagam, "Modeling the machining parameters of AISI D2 tool steel material with multi wall carbon nano tube in spark machiningprocess using response surface methodology ", *International Journal of the Physical Sciences,* 2012.

S. Prabhu and then B.K. Vinayagam, “Analysis of surface characteristics of AISID2 tool steel material using Electric Discharge Machining process with Single wall carbon nano tubes” *International Journal Machining and then Machinability of Materials*, (2011.

S. Prabhu and then B.K. Vinayagam, “Analysis of Surface Characteristics of AISI D2 Tool Steel Material Using Carbon Nano Tube”, *International Journal of Nanotechnology and then Applications*, 2008.

Tan, P. C. and then S H Yeo, “Investigation of recast layers generated by a powder-mixed dielectric micro spark machiningprocess”, *Journal of Engineering Manufacture*, 2011

The Behavior of Graphite and then Copper Electrodes On The Finish Die-Sinking Spark machining(SM) Of AISI P20 Tool Steel, Fred L. Amorim Walter L. Weingaertner, *Journals of the Brazil Society of Mech. Science & Engg.* 2007.

The Implementation of Taguchi Method on SM Process of Tungsten Carbide, Mohd Amri Lajis, H.C.D. Mohd Radzi, A.K.M. Nurul Amin, *European Journal of Scientific Research,* 2009.

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