A Detailed Review of Input and Output Parameters of EDM

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Abstract- Electrical discharge machining (EDM) is one of the most extensively used nonconventional material removal process based on controlled thermo-electric erosion of metals by the intense heat of electric repetitive spark discharges between electrode and the workpiece immersed in a dielectric fluid having applications in mould, die ,automotive ,nuclear ,aerospace surgical components to a micro–scale applications. In the present paper, a detailed review study of input and output parameters of EDM has been presented.
Keywords – Electrical discharge machining (EDM), parameters, Nonconventional machining

I. INTRODUCTION

Electrical discharge machining (EDM) is one of the most extensively used nonconventional material removal process based on controlled thermo-electric erosion of metals by the intense heat of electric repetitive spark discharges between electrode and the workpiece immersed in a dielectric fluid having applications in mould, die ,automotive, nuclear ,aerospace surgical components to a micro–scale applications [1,2,3] . In EDM , material is not subjected to mechanical stresses as there is no physical contact between the tool and work so it can machine the material of all types of conductive materials (metals, metallic alloys graphite , ceramics , composites etc) [4]

Fig 1 shows the concept of EDM. When sufficient voltage (electric field higher than the dielectric rigidity of the fluid of the small gap) is applied between the electrode and the workpiece, the dielectric fluid ionizes and forms a plasma channel (ionized, electrically conductive gas with high temperature) that melts and vaporizes the material located on the surface of the workpiece[5]. As the metal removal per discharge is very small, discharges should occur at high frequencies. The thermal energy generates a channel of plasma between the cathode and anode at a temperature in the range of 8000 to 12,000 °C or as high as 20,000°C initializing a substantial amount of heating and melting of material at the surface of tool as well as workpiece. When the pulsating direct current supply occurring at the rate of approximately 20,000–30,000 Hz is turned off, the plasma channel breaks down. This causes a sudden reduction in the temperature allowing the circulating dielectric fluid to implore the plasma channel and flush the molten material from the pole surfaces in the form of microscopic debris. [1].This results in formation of very small crater on the work surface at the point of discharge. Repeated such craters formed continuously on the work surface leads on to the machining to the required shape. There will be erosion of the tool electrode also but it will be less compared to the material removed from workpiece. First is due to lower moment of striking positive ion on the cathode compared to higher momentum of electrons stream impinging on the work anode surface. Secondly compressive force generated at cathode by the spark generated also helps in reducing tool electrode wear. Thirdly Carbon cracked from dielectric kerosene deposits on the electrode surface and forms a protective layer during machining. This carbon layer protects the surface of the electrode from spark erosion. The increase of peak current tends to increase the carbon layer which tends to decrease the tool wear [6].

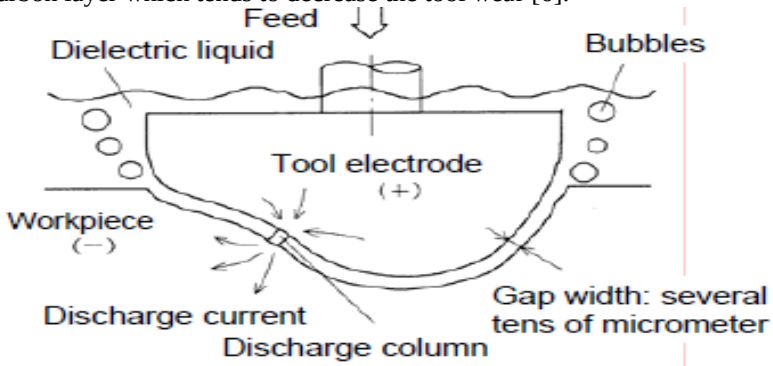

Figure 1: Concept of EDM.

II. TYPES OF EDM

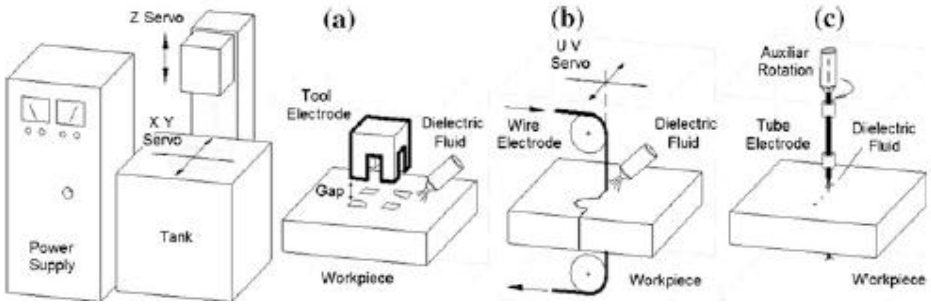

Figure 2(a) sinker EDM (b) Wire EDM (c)Fast hole drilling machine

2.1 Sinker EDM

The workpiece is immersed into a dielectric (electrically non-conducting) fluid and connected to a terminal of a DC power supply while the tool-electrode is immersed at some gap from the workpiece and connected to the other terminal the main applications of sinker EDM are the fabrication of blind cavities and hole drilling using electrodes machined from graphite or copper to the desired shape of the cavities and holes.

2.2 Wire EDM

The working principle of wire EDM is similar to that of sinker EDM, but instead of using an electrode that slowly plunges into the workpiece, it uses a traveling wire electrode (made from copper, brass, or molybdenum with diameters ranging from 0.01 to 0.5 mm) that passes through the workpiece to remove material. In order to feed the wire electrode through the workpiece, an initial hole must often be drilled in the workpiece prior to wire EDM.

2.3 Fast hole EDM drilling

This EDM is used for drilling of holes in any electrical conductive Material, whether hard or soft, including tungsten carbide. The term 'fast hole EDM drilling' is used to distinguish the process from sinker EDM which can also be used for drilling holes but in much slower speeds. The working principle of fast hole EDM drilling is similar to that of conventional EDM, and major differences are related to the fact that electrodes rotate and are
hollow. The rotating electrode helps ensuring better concentricity and reducing wear, while the hollow features allow dielectric fluid to flow through the electrode directly to the working gap.

2.4 Micro EDM

The recent trend in reducing the size of products has given micro-EDM a significant amount of research attention. Micro-EDM is capable of machining not only micro-holes and micro-shafts as small as 5μm in diameter but also complex three-dimensional (3D)micro cavities Micro EDM process is basically of four types: micro-wire EDM, die-sinking micro-EDM, micro EDM drilling and micro-EDM milling. In micro-wire EDM, a wire which has a diameter down to 0.02 mm is used to cut through a work piece. Indie-sinking micro-EDM, an electrode is used containing micro-features to cut its mirror image in the work piece. In micro EDM drilling, micro-electrodes (of diameters down to 5–10 μm) are used to 'drill' micro-holes in the work piece. In Micro-EDM milling, micro-electrodes (of diameters down to 5–10 μm) are employed to produce 3D cavities by adopting a movement strategy similar to that in conventional milling.

2.5 Powder mixed EDM (PMEDM)

A suitable material in the powder form(silicon carbide, aluminum , graphite powder) is mixed into the dielectric fluid of EDM. The chain formation helps in bridging the gap between both the electrodes, which causes the early explosion. Faster sparking within discharge takes place causes faster erosion from the workpiece surface. MRR SQ generally increases with addition of powder into the dielectric fluid.

2.6 Dry EDM

A thin walled pipe is used as tool electrode through which high-pressure gas or air is supplied gas is to remove the debris from the gap and cooling of the interelectrode gap. The technique was developed to decrease the pollution

caused by the use of liquid dielectric which leads to production of vapors during machining and the cost to manage the waste [5, 8, 3, 9]

III. LITERATURE REVIEW

Authors /Title and Journal/ Conference Name	Research Objectives and Research Methods	Major Findings	Conclusion and Future Scope
1. K.H. Ho, S.T. Newman / State of the art electrical discharge machining (EDM) / International Journal of Machine Tools & Manufacture 2003	To achieve more efficient metal removal coupled with a reduction in tool wear and improved surface quality	Performance commonly measured in terms of MRR, TWR and SR have been made with an overwhelming research interest being paid to the metallurgical properties of EDM machineed part.	The basis of controlling the EDM process mostly relies on empirical methods largely due to the stochastic nature of the sparking phenomenon involving both electrical and non-electrical process parameters. The complicated interrelationship between the different optimized process parameters is therefore a major factor contributing to the overall machining efficiency
2. Seung-Han Yanga,∗ , J. Srinivas a, SekarMohana, Dong-MokLeea, SreeBalaji b Optimization of electric discharge machining using simulated annealing/ Journal of Materials Processing Technology 2009	To Optimize MRR and roughness value / Counter propagation neural network (CPNN)	The system model is created using CPNN using experimental data.Algorithem and flow chart is shown in this paper. The process parameters considered in experiments include discharge current (I), source voltage (V), ulse-on time (Ton) and pulse-off time (Toff)	A reliable function generated from counter-propagation neural network was employed to evaluate the non-dimensional multiple objective values. can be extended to consider more number of operating parameters in studying their effect on material removal rates and surface roughness values.
3. .J.A.McGeough,H.Rasmussen A Macroscopic model of electro-discharge Machine / International Journal of Machine Tool Design and Research1982	To formulate theoretical macroscopic model on for replacing the usual time dependent field by a stead field to avoid random nature of EDM	The electric field needed for the production of sparks in the inter-electrode gap must exceed critical value. sparks occurs over electrode regions at which the local field is highest. the rate of metal removal is proportional to the energy transmitted by the sparks.	For constant spark gap (taking parallel electrodes). the wear ratio varies directly with the electrode velocity, Two dimensional electrode formulations. Numerical method of solution
4. M. Kunieda1 , B. Lauwers2 K. P. Rajurkar3 B. M. Schumacher4 Advancing EDM through Fundamental Insight into the Process / CIRP Annals -	To focus on gap phenomena as criticality and its related factors measurement .	Fundamental studies of gap phenomenon with newly developed advanced technologies(surface analyzing	Reviewed all parameters and their interrelations with basic insight in fundamentals of process. discharge gap phenomenon considering EDM is complex

Manufacturing Technology 2005		equipments, microscopes, high-speed imaging devices, and software tool)	process.
5. Md. Ashikur Rahman Khana,*, M. M. Rahmanb, K. Kadirgamab Neural network modeling and analysis for surface characteristics in electrical discharge machining / Procedia Engineering 10th International Conference on Mechanical Engineering, ICME 2013	To develop an ANN model that accurately correlates the EDM process variables as peak current, pulse-on time, pulse-off time, servo-voltage and performance, namely surface roughness (Ra) of Titanium Alloy, Ti 5-2.5 / ANN	the surface roughness (Ra) is considered as response parameter, and parameters such as peak current, pulse-on time, pulse-off time (and servo-voltage are selected as EDM variables and their effects explained through ANN	The developed neural network model is adequate for prediction the surface roughness. high discharge energy produces deeper and wider craters, resulting in a rougher surface and vice versa.
6. Norliana Mohd Abbas, Darius G. Solomon, Md. FuadBahari A review on current research trends in electrical discharge machining (EDM)/ International Journal of Machine Tools & Manufacture 2007	This paper reviews the research trends in EDM on ultrasonic vibration, dry EDM machining, EDM with powder additives, EDM in water and modeling technique in predicting EDM performances.	Review all aspects of trend for last 25 years with both EDM and WEDM	The ultrasonic vibration method is suitable for micro machining, dry machining is cost effective, EDM in water is introduced for safe and conducive working environment, EDM with powder additives is concerning more on increasing SQ, MRR and tool wear using dielectric oil and EDM modeling is introduced to predict the output parameters which leads towards the development of precise and accurate EDM performance.
7. M. L. Jeswani Dimensional analysis of tool wear in electrical discharge machining / Wear, Elsevier 1979	To determine the thermo physical properties of electrode materials which affect tool erosion.	The erosion phenomenon was analyzed by dimensional analysis	An empirical equation was obtained which relates the volume of material eroded from the tool electrode to the energy of the pulse, density, thermal conductivity, specific heat and latent heat of vaporization of the electrode material.
8. Cheol-Soo Lee a, Eun-YoungHeo b, Jong-MinKim b, In-HughChoi c, Dong-WonKim Electrode wear estimation model for EDM drilling / Robotics and Computer-Integrated Manufacturing 2015	this paper presents an effective model to esti mate the electrode wear of micro-EDM drilling	The wear amount depends on discharging environment such as material type and hole shapes.	This paper suggested meaningful wear estimation model through exponential curve fitting
9. P. S. Ng1 & S. A. Kong1 & S. H. Yeo1	Use of Canola Bio diesel (BD)and sunflower BD as	Bio diesel (BD)has the potential to replace	The MRR of canola and sunflower BD is approximately 114 to 137 %

Investigation of biodiesel dielectric in sustainable electrical discharge machining / International journal of advanced manufacturing technology 2016	dielectric for sustainable EDM / Analysis of variance (ANOVA)	conventional dielectric for a more sustainable machining process.	higher than the MRR when conventional dielectric.The TWR, canola and sunflower BD performed approximately 21 to 42 % better than conventional dielectric in both low and high palm oil and coconut oil as BD Explorations on the options of treatment of used BD to recycle or recondition would be required.
10. Janak B. Valakia,b,, Pravin P. Rathodc, C.D. Sankhavarad Investigations on technical feasibility of Jatropha curcasoil based bio dielectric fluid for sustainable electric discharge machining (EDM) / Journal of Manufacturing Processes 22 (2016) 151–160	Use of Canola Bio diesel (BD)and sunflower BD as dielectric for sustainable EDM / Analysis of variance (ANOVA)	Bio diesel (BD)has the potential to replace conventional dielectric for a more sustainable machining process.	The MRR of canola and sunflower BD is approximately 114 to 137 % higher than the MRR when conventional dielectric.The TWR, canola and sunflower BD performed approximately 21 to 42 % better than conventional dielectric in both low and high energy settings. palm oil and coconut oil as BD Explorations on the options of treatment of used BD to recycle or recondition would be required.
11. Cheol-Soo Lee a, Eun-YoungHeo b, Jong-MinKim b, In-HughChoi c, Dong-WonKim /Electrode wear estimation model for EDM drilling / Robotics and Computer-Integrated manufacturing 2015	this paper presents an effective model to esti mate the electrode wear of micro-EDM drilling	The wear amount depends on discharging environment such as material type and hole shapes.	This paper suggested meaningful wear estimation model through exponential curve fitting
12. Naotake Mohril, Masayuki Suzuki, Masanori Furuya, Nagao Saito' -Akira Electrode Wear Process in Electrical Discharge Machining / CIRP Annals - Manufacturing Technology	Study of electrode wear Taking account of the precipitation of turbostratic carbon on the electrode,	It is found that the edge portion of the electrode wears remarkably at the beginning of machining	Low wear of electrode is realized due to the precipitated turbo stratic carbon on the electrode surface
13. Hamid Reza FazliShahri, RamezanaliMahdavinejad,Mehdi Ashjaee, Amir Abdullah A comparative investigation on temperature distribution in electric discharge machining process through analytical, numerical and experimental methods / International Journal of Machine Tools & Manufacture 2017	To predict the Temperature distribution by analytical, numerical and experimental investigation and These results are compared with real temperature distribution	Reviewed all methods and mathematical models of prediction and measurement of temperature distribution. researchers' studies can be divided into three separate approaches, namely the	Reviewed and Suggested procedures of output parameters based on temperature distribution to assign the prerequisites of modeling and facilities needed for experimental studies.enhance the accuracy of temperature prediction, to facilitate choosing the approach (or a combination of approaches) for

		analytical, numerical and experimental analysis	temperature distribution analysis. 1.investigation on a comprehensive theoretical model containing the non-Fourier law of heat conduction 2.Determining the thickness of white layer, molten-resolidified layer and recrystallization layer of the workpiece 3.A need for deeper investigations on how microstructural changes and grain size can affect the thermo-physical properties (especially thermal conductivity and specific heat) and temperature distribution is felt
.14.J. Marafona, J.A.G. Chousal A finite element model of EDM based on the Joule effect / International Journal of Machine Tools & Manufacture 2006	To develop A thermal–electrical model for sparks generated by electrical discharge in a liquid media in EDM / FEA/ ABAQUS Standard	The 2D axisymmetric finite element has an easier formulation than the 3D finite element and allows a reduction in the CPU time with very similar results	With the new FEA model for the EDM process it is possible to estimate the surface roughness, the removed material from both anode and cathode and the maximum temperature reached in the discharge channel
15. Kesheng Wang, Hirpa L. Gelgele, Yi Wang, Qingfeng Yuan, Minglung Fang A hybrid intelligent method for modelling the EDM process / International Journal of Machine Tools & Manufacture 2003	To develop a hybrid approach to develop a model and optimize EDM process / . GA& ANN	This paper discusses the development and application of a hybrid artificial neural network and genetic algorism methodology to modelling and optimization of electro-discharge machining	A mechanism that combines the important capabilities of ANNs and GAs has been developed and implemented. the solutions achieved .establish better knowledge about the interaction between the tool (graphite) and the work piece (nickel based alloy) for the process. Testing the model with more data, verification of the results and optimizing the model with respect to the structure of the neural network.
16. Y. Guo , Z. Ling A magnetic suspension spindle system for micro EDM / Procedia CIRP 543 – 546 18th CIRP Conference on Electro Physical and Chemical Machining (ISEM XVIII) 2016	To introduces the structure and principle of the magnetic suspension spindle device used for micro EDM	Hardware and software solutions of the control system OF SPINDLE are illuminated by schematic diagram and flow chart	Axial response frequency of the magnetic suspension spindle reach 150Hz, which is more than that of the traditional mechanical transmission (5~20Hz).the radial and axial position accuracy is 5μm and 2μm in the range of stroke (1.3mm).

17. Y. Zhang, Y. Liu, Y. Shen, Z. Li, R. Ji, F. Wang A new method of investigation the characteristic of the heat flux of EDM plasma / Procedia CIRP The Seventeenth CIRP Conference on Electro Physical and Chemical Machining (ISEM) 2013	To investigate the heatflux characteristic in the EDM plasma comparing the boundary of the molten material obtained by metallographic method and the isothermal surface of the thermal-physical model calculated by finite element method (FEM) /FEM	The Gaussian heat source was more consistent with the actual EDM case	1.With the Gaussian heat source, the simulated results can be very close to the experiment results. 2.The energy distributed ratio into workpiece was nearly 50%
18. B. Izquierdo, J.A.Sa´ nchez, S.Plaza,I.Pombo,N.Ortega A numerical model of the EDM process considering the effect of multiple discharges / International Journal of Machine Tools & Manufacture 2009	To model and simulate the EDM process by considering multiple discharges. / Finite difference method	Temperature fields within the workpiece generated by the superposition of multiple discharges are numerically calculated using a finite difference schema	Error in the prediction of surface finish is under 6% and the error in the prediction of material removal rate is lower than3%.
19. Chinmaya P. Mohanty · SibaSankarMahapatra · ManasRanjan Singh A particle swarm approach for multi-objective optimization of electrical discharge machining process / Journal of Intelligent Manufacturing 2016	optimization of various machining parameters for the die-sinking EDM process using a multi-objective particle swarm (MOPSO) algorithm to estimate the effect of machining parameters on the responses / A Box–Behnken design of response surface methodology/ Particle -swarm optimization algorithm(PSO A	In this study, four responses such as (MRR, EWR, surface roughness and radial overcut) are considered., two responses are considered to be optimized treating other two responses are treated as constraints at a time.	Tool material, discharge current and pulse-on-time are found to be the important parameters for all the responses. Flushing pressure is found to be an insignificant parameter for all the responses.
20. T. Muthuramalingam , B. Mohan	overview of the EDM process,	The lower energy pulses enhance the surface finish	It has been found that peak current and pulse

A review on influence of electrical process parameters in EDM process / Archives of Civil and Mechanical Engineering 2014	modeling of process parameters, and influence of process parameters such as input electrical variables, pulse shape, and discharge energy on performance measures such as material removal rate, surface roughness and electrode wear rate	of the workpiece whereas the higher energy pulses improve the material removal rate	duration are dominating the performance measures in EDM process
21. Mudimallana Gouda, Apurbba KumarSharma, ndrashekharJawalkar A review on material removal mechanism in electrochemical discharge machining (ECDM) and possibilities to enhance the material removal rate / Precision Engineering 2016	overview of ECDM process and their improvement methods	In ECDM process both EDM and ECM processes are taking place simultaneously, but at different places	Four methods has been proposed for improvement of performance of ECDM process.1.optimum amount of electrolyte2.rotation to the tool-electrode3.abrasive mixed electrolyte along with appropriate tool-electrode motion.4.Maintaining constant gap between tool-electrode and workpiece.further investigation (MRR, SR, TWR) facilities like high speed cameras to study the gas film formation and nature of sparking/The MRR in ECDM can be enhanced by using suitable elec-trolyte and its concentration.
22. M.P. Jahan, M. Rahman , Y.S. Wong A review on the conventional and micro-electrodischarge machining of tungsten carbide / International Journal of Machine Tools & Manufacture 2011	The objective of this paper is to provide a state of the art in the field of EDM and micro-EDM of tungsten carbide(WC) and its composites(WC-Co).	A common problem of micro-EDM is that the circulation of dielectric and the removal of machined-debris are very diffi-cult, especially when the hole or the cavity becomes deep in tungsten carbide,which limits the machining efficiency and aspect ratio of the holes to be lower	Reviewed all aspects of tugustenand their composite machining by sink and micro EDM with basic insight in fundamentals of process to develop new pulse generator capable of providing very small discharge energy during machining.energy in nano joule per pulse range or modification of the

			scanning tunnelingmicroscope(STM) platform can help in successful nano-EDM of tungsten carbide
23. Yih-fongTzeng , Fu-chen Chen A simple approach for robust design of high-speed electricaldischarge machining technology / International Journal of Machine Tools & Manufacture 2003	To optimize the high speed EDM coupled withTaguchi methods for process optimization /Taguchi method, ANOVA, orthogonal array	To increase its speed, a large electrical current discharge is normally used, but this will inevitably compromise the dimensional accuracy of the machined product.	The most important factors affecting the EDM process robustness have been identified as pulse-on time, duty cycle, and pulsed peak current.
24. K. P. RajurkarS. M. Pandit , A Stochastic Approach to Thermal Modeling Applied to Electro-Discharge Machining / Journal of Heat Transfer 1983	The paper illustrates thermal modeling of this process with the help of a recently developed stochastic methodology called Data Dependent Systems (DDS). / DDS (EMPERICAL	developing a meaningful physical representation of a complex and random process by the integration of Data Dependent Systems model with the laws of physics, can be applied to many other similar engineering and scientific situations.	It predicts more accurate results for actual machining conditions.
25. I. Puertas , C.J. Luis A study on the machining parameters optimisation of electrical discharge machining / Journal of Materials Processing Technology 2003	Optimization of surface quality and dimensional precision in sink EDM. / Designof experiment(DOE), regression analysis. Surface response methodology	Developed mathematical model . Represented the nature of time in(ti) , time off (to)and peak current (I) on surface quality & dimensional precision with surface response	Factor of intensity is more influence on surface roughness due to better arc stability. High peak current (I) and low ti combination is suggested for the same.
26. .Ajit S , Amitabha Ghosh A thermo-electric model of material removal during electric discharge machining / International Journal of Machine Tools & Manufacture 1999	A thermo electric model is proposed for material removal cosideringelectrosatic force , types of pulses and crater formation	The crater depth increases with the voltage applied between the electrodes and the total current in the discharge.	The model suggests that the electrostatic forces are the major cause of metal removal for short pulses and melting becomes the dominant phenomenon for long pulses
27.	This paper	Fuzzy-expert rules (IF–	The system is a compact

Oguzhan Yilmaz , Omer Eyercioglu , Nabil N.Z. Gindy A user-friendly fuzzy-based system for the selection of electro discharge machining process parameters / Journal of Materials Processing Technology 2006	introduces a user-friendly intelligent system for the selection of electro discharge machining (EDM) parameters based on expert rules, which were obtained from experimental results and extracted from the knowledge of skilled operators / Fuzzy logic	THEN rules), membership functions and defuzzification methods are all used to eliminate the complexity of the situation	and homemade tool that can be easily used by an average operator and provides the EDM parameters which lead to less electrode wear, better surface quality and more erosion rate for the selected operation
28. HaoTonga,b, Long Zhanga, Yong Lia,ba Algorithms and machining experiments to reduce depth errors in servo scanning 3D micro EDM / Precision Engineering 2014	The purpose of this research is to efficiently machine complex 3D micro-cavities with high accuracies of shape and surface	a layer depth constrained algorithm (LDCA) and an S-curve accelerating algorithm (SCAA) were proposed to reduce the depth errors	3D micro cavities <800µ can be automatically machined, and the machining accuracies of micro surfaces and edges are obviously improved, and the depth errors can be controlled within 2 micron, and the MRR reaches 2.0 × 104 m3/s with tool electrode of Ø 80 µ and its rotational speed of 1000 r/min
29. ArindamMajumder, Pankaj Kumar Das,Abhishek ajumder&Moutushee Debnath An approach to optimize the EDM process parameters using desirability-based multiobjective PSO / Production & Manufacturing Research (taylor& Francis) 2014	to optimize the EDM process parameters using desirability based multi objective PSO / Surface Response Methodology, desirability-based multi-objective particle / swarm optimization (DMPSO)	The predictive performance of PSO-CF(contraction factor) is better than that of PSO-O(original) and PSO-WI(weight inertia) and PSO-CF find a good scope in optimization of EDM process parameters	The MRR of the optimal parameter design has increased by 86%, whereas there is a significant reduction in EWR by 28.4%.
30. S. Tariq Jilani and P.C. Pandey Analysis and modelling of EDM parameters / Precision Engineering	To study the effects of edm input parameters by	Many missed and short circuit pulses, which do not contribute to metal removal,are	metal removal in EDM is not only due to melting but also to vaporization, thus

1982	two dimensional heat source model	encountered.This would also result in less metal removal per pulse than that predicted Theoretically.	greatly reducing the heat available for conduction
31.. Y. Chen, S.M. Mahdivian Analysis of electro-discharge machining process and its comparison with experiments/ Journal of Materials Processing Technology 2000	To estimate the material removal rate and surface quality of the workpiece by Theoretical model	The experimental values of the material removal rate follow the same trend as the theoretical results and are slightly lower than the theoretical estimate	Model has provided the equations to calculate the workpiece MRR and Surfaceroughnees The validated theoretical analysis may be applied to the adaptive control of the EDM, to improve the efficiency of the EDM process, the surface quality and the accuracy of the workpiece.
32. Z. Katz · C.J. Tibbles Analysis of micro-scale EDM process / The International Journal of Advanced Manufacturing Technology 2005	To understand the phenomenon of electrode size on discharge process through model	The model suggested using dimensionless groups that predicts reasonable values for the current density, crater area, power dissipation,and the rate of channel growth	Model has provided the equations to calculate the workpiece MRR and Surfaceroughnees The validated theoretical analysis may be applied to the adaptive control of the EDM, to improve the efficiency of the EDM process, the surface quality and the accuracy of the workpiece.
33. P. Shankar , V. K. Jain & T. Sundararajan Analysis of spark profiles during EDM process / Machining Science And Technology 1997	To study the spark profile through mathematical modelling	The spark radius decreases with a decrease in IEG (inter electrode gap)so MRR also decreases .	The spark profile is found to be noncylindrical with the smallest cross section occurring at the middle of a discharge. IEG(gap), pulse duration, and pulse current are found to have a significant effect on MRR
34. Rogério F. Santos, Ernane R. Silva, Wisley F. Sales* and Alberto A. Raslan Analysis of the surface integrity when nitriding AISI 4140 steel by the sink electrical discharge machining (EDM) process / Procedia CIRP 3rd CIRP Conference on Surface Integrity (CIRP CSI) 2016	Nitriding by Sink EDM and their effect on surface integrity	The nitriding mechanism in EDM,due to the high temperatures and short discharge times Involved in the process. Urea is a source of nitrogen.	The use of electrical discharges generated from EDM using urea dissolved in deionized water as the dielectric fluid resulted in surface hardening of steel samples
35. .U. Maradia, M. Boccadorob, J. Stirnimannc, I. Beltramib, F. Kustera, K. Wegenera Die-sink EDM in meso-micro machining / Procedia CIRP 5th CIRP Conference on High	To analize die-sink EDM in meso - micro scale machining by concentrating on primary	lower accuracy of machined parts is expected due to positioning errors involved while machining and changing tool electrodes.hand-written cam strategy was used and	Low tool wear technology was developed for using graphite electrodes in meso-micro EDM offering economical and energy efficient solution in meso-micro scale machining

Performance Cutting 2012	process parameters to obtain highMRR, low TWR with high form accuracy and precision with low wear technology.	optimised to achieve precise form of the electrode with high accuracy	
36. NaotakeMohril, Masayuki Suzuki, Masanori Furuya, Nagao Saito' - Akira Electrode Wear Process in Electrical Discharge Machining / CIRP Annals - Manufacturing Technology 1995	Study of electrode wear Taking account of the precipitation of turbostratic carbon on the electrode,	It is found that the edge portion of the electrode wears remarkably at the beginning of machining	Low wear of electrode is realized due to the precipitated turbostratic carbon on the electrode surface
37. B. M. Schumachera*, R. Krampitzb, J.-P. Kruthc/ Historical phases of EDM development driven by the dual influence of "Market Pull" and "Science Push"./ Procedia CIRP The Seventeenth CIRP Conference on Electro Physical and Chemical Machining (ISEM)	"Market Pull" and "Science Push"for EDM from history Historical phases discussed keeping both institutional research and industrial demand	advantages of EDM in autonomous machining of complex forms and in independency from workpiece hardness will keep this process in front.	A minimum of interfaces will be helpful for best flexibility. sustainability is not valid if there is no competitiveness Intelligent design, energy savings, re-use and re-cycling facilities are the future scope
38. Rimao Zou, Zuyuan Yu∗ , Wei Li, MeigangGuo, Jianzhong Li Influence of porous structure on the machining performance of micro EDM / Journal of Materials Processing Technology 2016	To find and compare MRR and TWR of porous and solid material.	High pore size leads to high debris removal ability so high MRR.	It was foundt hat the MRR of porous material is larger than that of solid material.2.The MRR increases with an increase of pore size
39. C. L. Lin, J. L. Lin and T. C. Ko Optimisation of the EDM Process Based on the Orthogonal Array with Fuzzy Logic and Grey Relational Analysis Method / International journal of advanced manufacturing technology2002	This paper objective is to Optimize the EDM process(minim um electrode wear ratio, surface roughness and maximum material removal rate,) by Orthogonal Array with Fuzzy Logic and Grey Relational Analysis Method and	Discharge current and pulse on time are the most significant process parameters affecting the multiple process responses.	The method based on the orthogonal array with the grey relational analysis method is more straightforward than the fuzzy-based Taguchi method for optimizing the EDM process with the multiple process

	compare / Fuzzy logic analysis, Grey relational analysis, Multiple responses, Taguchi method,ANOVA		
40. J.L. Lina,*, K.S. Wangb, B.H. Yanb, Y.S. Tarngc Optimization of the electrical discharge machining process based on the Taguchi method with fuzzy logics / Journal of Materials Processing Technology 2000	To optimize the electrical discharge machining process based on the Taguchi method with fuzzy logics with multiple performance characteristic / Fuzzy logic analysis, , Taguchi method	Optimizing the electrical discharge machining process with multiple performance characteristics has been reported.Themachining parameters (the workpiece polarity, pulse-on time, duty factor, open discharge voltage, discharge current and dielectric ¯uid) are optimized with considerations of the multiple performance characteristics	current and pulse off time are more significant factor for MRR
41. Sumit Raja, Kaushik Kumarb Optimization and Prediction of Material Removing Rate in Die Sinking Electro Discharge Machining of EN45 Steel Tool. / 4th International Conference on Materials Processing and Characterization, Materials Today: Proceedings 2015	MRR optimization of EN 45 steel in sink / Taguchi method, L 27 Arthogonal array , ANOVA, Regression analysi	Research originated from research gap for EN 45 Material. Optimization has been done for maximization of MRR by using experimental value no research work has been reported in EDM of EN45 material to find out the MRR.	work Predicted value for optimal parameters compared with its experimental value and the improvement in S/N ratio was found
42. Hsien-Ching Chen a, Jen-Chang Lin b, Yung-Kuang Yang b, Chih-Hung Tsai / Optimization of wire electrical discharge machining for pure tungsten using a neural network integrated simulated annealing approach / Expert Systems with Applications 2010	to determine an optimal parameter setting of the WEDM process / A method integrating back-propagation / neural network (BPNN) and simulated annealing algorithm (SAA) , ANOVA,Taguchiarthogonal array L18	This study analyzed variation of cutting velocity and workpiece surface finish depending on wire electrical discharge machining (WEDM) process parameters during manufacture of pure tungsten profiles	proposed algorithm and confirmation experiments are show that the BPNN/SAA method is effective tool for the optimization of WEDM process parameters.

43. P.C.Pandey∗ S.T.Jilani Plasma channel growth and the resolidified layer in edm / Precision Engineering 1986	1.To compute the plasma channel size 2.To evaluating the thickness of the resolidified layer in EDM machined workpieces	Erosion is strongly dependent on the thermo physical constants of the electrode material.only 10-20% of the total molten material is removed from the molten pool at the end of the pulse, while the remaining material resolidifies within the crater and its vicinity	The two-dimensional disc heat source model enables to obtain the thickness of heat-affected zone due to a single spark with a fair degree of accuracy, and a good correlation between the analytical and experimental values has been achieved.
44. NurSherilLokeBintiIzwan, Zhujian Feng, JigarBimal Patel, and Wayne Nguyen Hung Prediction of Material Removal Rate in Die-Sinking Electrical Discharge Machining / Procedia Manufacturing 2016	To predict material removal rate in die-sinking electrical discharging machining (EDM). / ANOVA , REGRESSION ANALYSIS	A two-pass EDM process should be practiced to achieve both high MRR and surface quality. The first roughing pass should use high charges (high current and long on-time) for high MRR; and the second finishing pass should use lower charges (low current, short on-time therefore EDM'ing at high sparking frequency) to remove the recast layer and possible defects while polishing the surface	Increasing the charge by setting a higher peak current and longer on-time would increase the MRR work would refine the model by considering thermal and electrical properties of the workpiece materials in additions to the process parameters
45. S. Chakraborty V. Dey S.K. Ghosh A review on the use of dielectric fluids and their effects in electrical discharge machining characteristics / Precision Engineering 2015	literature survey on the use of dielectric fluids and also their effects in electrical discharge machining haracteristics	Machining with water as dielectric has the possibility to achieve zero electrode wear while using copper tool is connected to the negative polarity. With distilled water, the machining accuracy is poor but the surface finish is better	It has been found that deionized water with organic com-pounds has an advantage over hydrocarbon dielectrics during discharges using long pulse duration and high pulse duty factor current. During micro-EDM, lower viscosity dielectric oils can improve the efficiency.

IV. PROCESS PARAMETERS IN EDM

Operating parameters

1. Gap voltage
2. Peak current
3. Pulse on time
4. Pulse off time
5. capacitance
6. Resistance
7. Polarity
8. Intensity of electric current and their properties.
9. Tool electrode (material and shape)
10. Dielectric Fluid(Properties and pressure and their ways to pressurize)
11. Work material and their properties.
12. Spark Gap
13. No of passes

Performance parameters

1. MRR(material removal rate)
2. Surface Quality(Ra value)
3. Tool wear ratio (TWR)
4. Overcut

[3,1]

Some observations are given below in tabled manner [5]

Peak current	Discharge duration	MRR	RA	TWR
high	high	high	not good	satisfactory(carbon deposited on anodde)
low	high	small	good	low
high	short	high	good	high(low caron layer)

4.1 Dielectric

The four basic functions of dielectric oil (specific to sinker EDMs and specially designed wire EDMs) are: insulation, ionization, cooling, and removal of waste particles.Die sink EDM generally operates with hydrocarbon oil, while wire, micro-EDM and fast drilling usually work with deionized water.

Types of dielectric being used are

Kerosene It has already been observed that pure kerosene, which is used as the dielectric liquid in most of the conventional EDM systems, creates several problems while machining, such as degradation of dielectric properties, pollution of air, and adhesion of carbon particles on the work surface.

2. Mineral oils Mineral oil or liquid petroleum is a by-product in the distillation of petroleum

3. Mineral seal oil derived from seal blubber was adopted by a number of aerospace companies as a dielectric fluid in the early days of EDM. it has been identified as having some potentially carcinogenic components, and thus its use is no longer recommended

4. Transformer oil is another mineral oil based product that wastailored for use in EDMs due to its dielectric properties. Earlier generations of transformer oil were compounded with PCBs. Trans-former oil has no current application in EDM.[9]

5. Biodiesel Jatropha BD, Canola BD and sunflower BD to ensure the sustainability of the EDM process so as to have a cleaner and greener environment required in green manufacturing.[10,11]

4.2 Tool electrode

Most commonly used materials for tool electrode are graphite due to high melting and vaporising temperature or copper due to high thermal conductivity.Other factors are also to be consider like MRR, TWR cost, availability etc.

The tool wear amount depends on discharging environment such as material type and hole shapes.[12,13]. Tool electrode movement may be axial , rotary or orbital is controlled through servo system. To maintain gap between tool and workpiece for stable machining.

4.3 Work material

All conductive materials irrespective of its hardness can machine by EDM. MRR of porous material is larger than that of solid material The MRR increases with an increase of pore size of material [13].

4.4 Electrical circuit

4.4.1 R- C Circuit

Generally used in wire EDM as required less spark energy

4.4.2 Transistor pulse generator circuit

It provides high MRR due to its high frequency discharge because there is no need of capacitor.

V. NEED FOR STUDY

EDM is the complex nature of the process involves simultaneous interaction of thermal, mechanical, chemical and electrical phenomena having stochastic nature so many parameters to achieve desired outputs such as high MRR and low surface roughness.

In EDM due to tool wear there will be more cost for machining. Selection of electrode material is important to be considered to prevent excessive tool wear. Most industries choose to reduce tool wear by optimizing the current supply and flushing pressure. To reduce machining time, industries use traditional machining such as milling for rough machining and followed by the EDM for finishing process. One of the industries implements the technique of using additives in dielectric in order to increase the MRR, to decrease Tool Wear Ratio (TWR) and to improve Surface Finish (SF). Surface finishing techniques such as polishing and chroming was applied by some of the industries in order to get better SF for the final products. Dimension, surface finish and machining time are the

important factors evaluated by industries. Dielectric consumption leads not only to environmental but also economical impact.
-Tool wear is severe problem with EDM. Number of passes has to be reduced
-Different tool materials can be considered
-Stochastic behaviour of EDM process so need good empirical model with assumptions.
-Selection of dielectric considering sustainable manufacturing.
-Different Workpiece materials and there layer formation due to rapid heading and cooling.
-Use of Optimization technique to get good results with less cost

VI. CONCLUSION

Electric discharge machining is one of nonconventional machining process extensively used in mould and die, aerospace , automobile industry applications. The main disadvantages are tool wear, low MRR and its environtal effects. To overcome these problems much work has been done by researchers but still there is need for some comprehensive solution for each problems. New Tool design through new materials, shapes for tool wear problem, MRR improvement through material study and other parameters, Different dielectrics for sustainable manufacturing and finally complete solution through optimization techniques is may be solution. This may apply to all types of EDM.

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