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Optimization of EDM Process Parameters by Using Artificial Neural Network: A Review

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Abstract: - Electrical discharge machining (EDM) is one of the most primitive and categorized non-conventional machining process. Edm is basically based on thermal spark generated between the tool and work piece in the presence of dielectric fluid. There are many performance parameters like pulse on (Ton), pulse off (Toff), current (A), gap voltage (v), flushing pressure, etc. are taken during experimental performance. Material removal rate (MRR), tool wear rate (TWR) or electrode wear rate (EWR), surface roughness (SR), etc. are used as response variables. These papers provide a review on the modelling and optimization of the machining parameters by using artificial neural network (ANN) in electrical discharge machining. The previous work done on the electrical discharge machining (EDM) is explained in this paper.
Keywords: - EDM, EDE, ANN, MRR, TWR, GA, SR

I. INTRODUCTION

In the EDM the removal of the work piece material is basically based on the electro discharge erosion (EDE). In this machining process the conductive material is machined by using sparks erosion method. The process occurs between tool and a work material in the presence of a die-electric fluid. Two Russian scientists B. R. and N. I. Lazarenko invented the electronic circuit which was known as relaxation circuit. In this circuit machining was formed by using a servo controller. The servo controller maintained the gap width between the tool and the work piece material. The principle of electrical discharge machining (EDM) is to use the eroding effect for the controlled electric spark discharges on the electrodes by the variation of the pulse. It is thus a thermal erosion process. Due to presence of dielectric fluid in between the work piece and electrode the electric spark is generated in it. The sparks are created in a dielectric liquid, generally water or oil, between the work piece material and the cutting tool or also known as electrode. There is no mechanical contact between the electrodes during the whole machining process. Since erosion is produced by electrical discharges, so both electrode tool and work piece material have to be a good conductor of electricity for the spark generation during the machining process **[1].** Metal material removal takes place as a result of the generation of extremely high temperatures generated by the highly intensify discharges that melt and evaporates the electrodes material.

II. ARTIFICIAL NEURAL NETWORKING (ANN)

A neural network is generally mathematical algorithm based technique. In this technique it modulate the operation of bio-logical neural system. In 1943, McCulloch and Pitts developed the technique with a logical calculus on the nervous activity. These were two mathematical bio physician **[2].** This technique give an inspection to the modern electronics. John von Neumann was known as an electronic brain. By this Frank-Rosenblatt was motivated by john von Neumann for the investigation on the computation of the eye. By this a new generation of neural networking was developed which was also known as perceptron **[3] [4].**

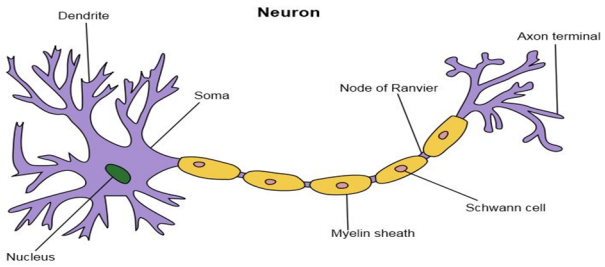

Figure:-2.1 Biological Neurons

The artificial neural network (ANN) was embolden by the biological neurons technique. This technique is related to human brain. There are large number of interconnection of neurons in human brain. As in case of the neural network, neuron acts as a modest

task, such as reaction an input signal. When even the number of hidden neuron are linked together, then different types of task can be performed. The task take millisecond to complete the optimization. Due to this it also show that human brain takes just a hundred computing stages to perform dissimilar task to performed and compare to millions of steps desired for computer to perform a specified task **[2]**. As shown in the figure body cells are defined as soma. Soma contain nucleus, just as the other cells. The branches associated to the body cells and extended in space to collect signals from other neurons are called dendrites. Axon are known as the transmitter of the neurons. These transmit the signal to the neighbourly neurons. Synapse are known as the association between the end of one neurons axon and the neighbourly neutron dendrites. These are specified as the communication unit formed between the two neurons **[3] [4].**

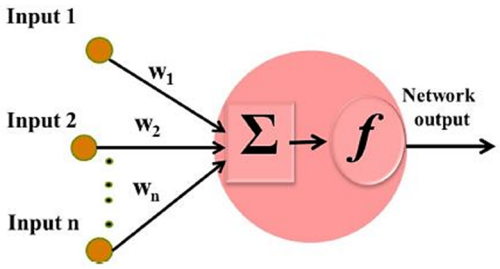

Figure: - 2.2 Artificial Neural Networking

ANN optimization improvement summary:-

So many research paper are published on electrical discharge machining (EDM).

In 1997 J.Y. Kao et al investigated on the electrical discharge machining by neural network approach. In the investigation the relationship between the tool and work piece were developed. Back propagation learning algorithm was preferred for creating the network. SKD11 as work piece and copper as an electrode were preferred. Gap voltage was measured between the tool and the work piece. For gap current current prob with its amplifier were measured. With the help of dual channel oscilloscope HP 54600A signal were monitored and recorded. GPIB was used as interface card which was used as the recording purposes. Pulses variation were observed with high accuracy. As it was observed that the monitoring system give high accuracy and very useful for monitoring **[5]**. In 2001 Tsai Predict on surface finish on an electrical discharge machining which was based upon neural network models. In the experimentation machining performance parameters were discharge time, current. For the response variable parameters surface roughness (SR) was considered in it. In the result it was compared on the predictions of surface roughness (SR) by smooth surface finish for diverse work materials based upon dissimilar types of six neural networks simulations and a neuro-fuzzy network model was revealed **[6]**. Su, Kao and Tarng in 2004 investigated on optimization of the machining process parameters of the electrical discharge machining (EDM) manner using a genetic algorithm GA-based neural network technique. Input variables were pulse on time, high-voltage expulsion current, pulse off time, low voltage, gap size, servo feed, and jumping time, working time. For the reaction variable surface roughness (SR), material removal rate (MRR) & tool wear rate (TWR) were considered. In the result it was decided that the industrialized of the neural network through the aid of a genetic algorithm (GA) has satisfactory forecast and reasoning capability to genetic optimal process factors from rough cutting stage to finish cutting phase during the course **[7].** In 2004 Fenggou and Dayong performed on the electrical discharge machining with the high proficiency and intelligent optimization system in the plunge process. The performance variable used as input were peak current and pulse width. The performance measured by as the response were by processing depth. The automatic determination and optimization of EDM sinking processing parameters by artificial neural network (ANN) are efficient and applicable in it. Automatic determination can be performed in it **[8].** In 2007 Debabrata Madal studied the modeling of the EDM process by neural networking. Back propagation was used as the network type in the neural networking modelling. Multi-objective optimization by non-dominating sorting by genetic algorithm was used. C-40 steel was considered as the work piece and copper as the electrode. Pulse on time, current with pulse off time was preferred as the input parameters. Where MRR and TWR was as response variables. It was concluded that the network model was suitable for predicting the response variables. By multi-objective optimization the objective to get high MRR was achieved **[9].** G Krishna, Mohana Rao and G Ranga Janardhana in 2008 optimized on the electrical discharge machining by the expansion of hybrid model of metal removal rate(MRR) with the implementation of artificial neural networks and genetic algorithm. The experimentation was conceded out on Ti6Al4V, HE15, 15CDV6 and M-250 work material. In the experiment peak current and

voltage were carried out as process parameters. And corresponding values for material removal rate (MRR) were measured as the response variables in it. In the neural network multi-perceptron neural network simulations were established for optimization of the weights the genetic algorithm was used in it. Sensitivity analysis was also done in it. Sensitivity analysis was performed to find encouragement of factors on the performance measure. It was concluded that types of material was having more influence on the performance dignified in it **[10].** In 2008 Markopoulos worked on Artificial neural network(ANN) modeling of surface finish in electro discharge machining of tool steel with process constraints as pulse current, pulse on time. Center- line average and the maximum height of the profile surface roughness were as the output variables during the processes. A feed forward training network was trained in ANN with the Levenberg Marquardt algorithm was employed for the prediction of the surface roughness **[11].** In 2008 Assarzadeh and Ghoreishi performed on the optimization and modelling of the Artificial Neural-network based on electrical-discharge-machining process (EDM). A network size of 3-6-4-2 size was developed for the process modelling in the electrical discharge machining (EDM). Back propagation network was developed in it. Current, periods of pulse, source voltage were performed as performance parameters. Material removal rate (MRR) and surface roughness (Ra) were taken as reaction variables. In the parallel process augmented Lagrange multiplier (ALM) algorithm define the optimal machining conditions by maximization of the material removal rate(MRR) and prescribed Ra constraints**[12].** In 2008 Rao, G.K worked on the improvement of hybrid model for the optimization of metal removal rate in electrical discharge machining by using Artificial Neural network and Genetic algorithm. For the progression parameters peak current, voltage were considered. Material removal rate were considered as an output variables. In the result it was determined that multi-perception neural network models where established using neuro Solutions package and Genetic algorithm (GA) theory is used to execute the optimization on the weighing factors of the neural network **[13].** G. Krishna in 2009 studied the enlargement of hybrid model and optimization on electrical discharge machining using artificial neural networks and genetic algorithm for the surface roughness (SR). The research was carried on Ti6Al4V, HE15, 15CDV6 and M-250 material. Experimentation were performed by varying the peak current (A), voltage (V) and surface roughness (SR) where measured in it. Neural network was executed in it. For multi optimization genetic algorithm method was used to optimize the weighting the factor used in neural networks. It was further observed by optimized genetic algorithm on the network the error has occurs less than 2% from 5%. Sensitivity analysis was also done in it **[14].** M. K. Pradhan Compare the caparison for the Neural Networking Models on the Electrical Discharge Machining (EDM) for the response parameters as the surface roughness (SR). Back propagation in neural network as a network type and radial basis function neural network were purposed on behalf of the cast of surface roughness (SR) of the electrical discharge machined surface. The results achieved from widespread experiments accompanied on AISI D2 steel work piece materials. For the machining factors copper electrode was used and these were associated and validated with the predictions. In the result it was pragmatic that the radial basis function network (RBFN) model was quit equivalent with back propagation network (BPN) for surface roughness prediction and both models offered an acceptable prediction in the result **[15].** Thillaivanan in 2010 optimizes the operating parameters for electrical discharge machining processes based on the taguchi method and artificial neural network with process parameters current, feed and total machining time. Stainless steel 340C and tungsten as work piece and electrode were considered respectively. Input and target values where setup with according to learning rate in it. For getting the machining time feed forward back propagation neural network was recognized. Over size and taper of a hole to was designed so it can be machined by Electrical discharge machining (EDM) **[16].** MahdaviNejad, R.A.in 2011 studied the Modeling and optimization of Sic Parameters, using Neural Network for the electrical discharge machining and Non-dominating Sorting in Genetic Algorithm (NSGA II) with process parameters Discharge current, pulse-on-time and pulse-off-time. The material removal rate (MRR) and surface roughness (SR) were considered as performance measured parameter. In this Refel Sic was used as a wok piece material and copper electrode were used as electrode. Artificial neural network was used with Back propagation algorithm network for the modelling of the processes. MRR and SR are optimized as objectives by using NSGA II **[17].** Yahya in 2011 performed the Material Removal Rate Prediction of high strength steel (HSS) on the Electrical Discharge Machining (EDM). Artificial Neural Network was used for modelling and optimizing the process parameters and there output parameters. For the process parameters gap current, pulse-on-time, pulse-off-time, sparking frequency were considered and material removal rate (MRR) was considered as the response parameters. Work piece material was conserved as high strength steel (HSS) and electrode was considered as the copper electrode. In the result it was concluded that the artificial neural network (ANN) model is capable of forecasting the material removal rate (MRR) with low percentage prediction error when these machining process parameters were compared with experimental result **[18].** Joshi in 2011 studied the modelling and optimization of the die-sinking electric discharge machining by artificial neural networking process. Discharge current, discharge duration, duty cycle, break down voltage, crater size were considered as the performance variables and response variable as MRR and TWR. AISI P20 mold steel was taken as the work

piece and copper was considered as the electrode material. Multi optimization was performed for the optimization of the machining process parameters. Artificial-Neural-Networking (ANN) process model was used to associate the genetic algorithm NSGA-II to select optional process parameters for roughness and finishing operation **[19].** Bharti, Maheshwari and Sharma in 2012 performed on multi-objective optimization on the INCONEL 718 as the work material on the electrical discharge machining processes by considering controlled elitist NSGA-II. Various process parameters were considered shape factor, pulse-on time, discharge current, duty cycle, gap voltage, flushing pressure, tool electrode lift time. Response parameters where material removal rate (MRR), surface finish. Copper was considered for the electrode material. The average percentage difference between experimental and artificial neural network (ANN) predicted value is 4 and 4.67 for MRR and SR respectively **[20].** Atefi in 2012 investigated the machining parameters in finishing stage on surface quality on electrical discharge machining by using Hybrid model. Numerous process parameters were considered as pulse current, pulse voltage, pulse-on-time, and pulse-off-time. For the performance parameter surface roughness. A hybrid model, combination of statistical analysis and ANN, is designed to reduce the error in optimization of complex and non-linear problems **[21].** In 2013 Bhavesh Patel, D.S. Patel and Haresh A. Patel worked on the Influence of an electrode material and process parameters for the surface quality and material removal rate(MRR) in electrical discharge machining (EDM). AISI H13 was considered as the work material and the copper was considered as the electrode material. For the optimization they consider artificial neural network. In the experiment he presents the modelling of artificial neural network (ANN) with the response variables as material removal rate (MRR), Tool wear rate (TWR) and surface roughness (SR). Gap voltage, Peak-current, Pulse-on-time, pulse-off-time and electrode material were taken as performance variables. AISI H13 was taken as work material. Neural network was consider to get a relation in between the input process variables and output process variables. As the result it was concluded that Levenberg- Marquardt training algorithm was more efficient for modelling process **[22].** Andromeda in 2013 Predicted on Material removal rate for EDM. For the optimization artificial neural network (ANN) was applied on the machining process parameters. Stainless steel was considered as the work piece where copper as an electrode. Process parameters as gap current, pulse-on-time, pulse-off-time, sparking frequency and performance parameters MRR were considered. In the result Andromeda concluded that the ability of neural network to track the dynamical behavior of the EDM process is indeed accurate for the processes **[23].** Tzeng and chen in 2013 performed on the JIS SKD 61 steel as the work piece material and copper electrode was used for the tool. Optimization of electric discharge machining process was accomplished by using the response surface methodology (RSM) and genetic algorithm (GA) approach. The process parameters discharge current, gap voltage, pulse-on-time, pulse-off-time were deliberated. As the performance parameters material removal rate, Surface roughness and electrode wear rate was considered. It was concluded in the result that the back propagation neural network (GPNN) and genetic algorithm (GA) gives healthier prediction results in the experimental runs than the regression models which was based on the response surface methodology (RSM) method **[24].** Agrawal in 2013 performed on the modeling and optimization of tool wear rate (TWR) in powder mixed EDM of metal matrix composite (MMC). Various processes were considered during experimentation. Process parameters as peak current, pulse-on-time, pulse-off-time, Powder concentration were considered and response parameters TWR was considered. Work piece material was made up of steel and electrode was made up of copper material. It was observed that mixing graphite powder in dielectric fluid significantly reduces the tool wear rate (TWR) during machining of MMC. The peak current has been identified as most significant control factor affecting TWR, followed by powder concentration. In this the developed ANN model is reliable and adequate to predict the TWR with negligible prediction error. **[25].** Ranjan Kumar Ghadai performed on the Modelling and optimization of Electrical Discharge Machining(EDM) Process Using Artificial Neural Network(ANN) for the Machining of Special Steel WP7V in 2014 and electrode material as copper was considered. Process parameters current and machining time. And response parameters as MRR and surface roughness were considered. Neural network with 0.9 learning rate and network architecture of 2-8-1 to 2-15-1 where applied in it. After 5000 iteration low Mean Square Error (MSE) obtained. It was observed that due to rise in current high MRR was obtained. It was due to applied high value of current the electrons are dense and owing to form an avalanche of the electrons in the spark gap where the process of ionization collision takes place. Due to generation of compression shock waves it develops the rise in the temperature of the material. The rise in temperature was sufficient to melt the metals was observed **[26].** V. Balasubramaniam in 2014 performed on the Optimization and modelling of Electrical Discharge Machining (EDM) Parameters Using Artificial Neural Network with Different Electrodes with the performance parameters pulse current, pulse on time, flushing pressure and different electrode material. Response variable as MRR, EWR and circularity. Different types of electrode of copper, brass and tungsten while machining on Al-SiCp metal matrix composite. Investigation shows that current is the most significant parameters. Among the three different electrodes copper yields better performances. Machining time also reduces with better performances **[27]**. Dragan Rodic and Marin Gostimirovic in 2014 Associated for the optimization and

modelling technique of Fuzzy logic and neural network for modelling Surface Roughness(SR) in EDM with the performance process parameters as discharge current and pulse duration. Both fuzzy logic and neural network were implemented for comparison. The results indicates that the NN model is an effective algorithm to predict the surface roughness in electrical discharge machining (EDM). The effectiveness of the models was only within the ranges and aspects studies **[28]**. In 2014 Yunn- Shiuan Liao et al studied the machining behaviour and parameters for the optimization of WEDM. Material type, discharge on time, discharge off time, arc on/off time, servo voltage, wire speed and flushing pressure were as the performance variables. Abnormal ratio, groove width, machining speed, surface roughness and spark frequency were considered as the response variables. Ti6Al4V (Ti alloy) and SUS304 (Stainless steel) as work material selected. L18 orthogonal array was selected for DOE with three level design. 8-15-5 network was created in the nntool. 0.5 As learning rate and 0.5 as momentum of coefficient was considered in neural network. For the optimization GA approach was performed. With the GA technique combination of the machining parameters were successfully achieved. Due to which machining time and cost factors get improved **[29].** In 2014 G.Ugrasen et al studied the estimation of machining performance of wire EDM. EN31 was considered as the work piece and molybdenum as tool material. MRA, GMD and ANN techniques were used for modelling of the network. Reuse of the wire was performed on four axes CNC WEDM (CONCORD DK7720c). Pulse on time, pulse off time, current and bed speed were considered as performance parameters. Surface roughness, material removal rate and accuracy were as response parameters. L16 orthogonal array was used for DOE. Back propagation feed forward neural network (BPNN) and Levenberg-Marquardt algorithm (LMA) were used for creating network. So it was observed that ANN function performed better predicted results than MRA and GMDH **[30]**.

Year	Author	Work piece material	Tool material	Machining Parameters	Response Parameters	Remarks
1997	J.Y. Kao et al [5]	-SKD11	-Copper	-Gap voltage -Gap current	-Gap signal	Monitoring system was generate high accuracy output and very useful for quick observation.
2001	Tsai, Wang[6]	-Aluminum -Iron	-Copper	-Discharge time -Peak current	-SR	Dissimilar types of six neural networks simulations and a neuro-fuzzy network model was revealed
2004	Su, Kao, Tarng [7]	-Steel	-Copper	-Pulse on time -High-voltage -Current -Pulse off time -Low voltage -Current, gap size -Servo feed -Jumping time -Working time,	-MRR -TWR -SR	Optimization of the machining process using a GA-based neural network. It was observed that GA has sufficient prediction and reasoning capability to generate optimal process parameters. The process were originated from rough to finish cutting stages.
2004	Fenggou et al[8]	-S136 steel	-Copper	-Peak current -Pulse width -Processing depth	-MRR	The processing parameters optimized and automatically determined were efficient and applicable.
2007	Debabrata Madal et al[9]	-C40 steel	-Copper	-Current -Pulse on time -Pulse off time	-MRR -TWR	Pareto-optimal set was predicted.
2008	Krishna et al[10]	-Ti6Al4V -HE15 -15CDV6 -M250	-Copper	-Peak current -Voltage	-MRR	Sensitivity analysis was performed to integrate in the performance measure.
2008	Markopoulos et al[11]	-St37 -C45 -100Cr6 -Dp1 -Mic/al 1	-Copper	-Current -Pulse on time -Center line average	-Maximum height of the profile surface roughness	Levenberg-Marquardt algorithm was considered with feed forward neural network for the prediction of the response variables.
2008	Assarzadeh et al[12]	-S136 steel	-Copper -Brass	-Current -Periods of pulse -Source voltage	-MRR -SR	Augmented Lagrange Multiplier (ALM) algorithm defines the optimal machining conditions with high MRR.
2008	Rao et al. [13]	-HS steel	-Copper	-Peak current -Voltage	-MRR	Development of hybrid model and optimization by ANN and GA.GA used to optimize the weighing factors of the neural network.

2009	Krishna Mohana et al [14]	-Ti6Al4V -HE15 -15CDV6 -M-250	-Copper	-Peak current -Voltage	-SR	GA method optimizes the weighting the factors used in neural network. Sensitivity analysis was also performed in it.
2009	M. K. Pradhan et al [15]	-AISI D2	-Copper	-Peak current -Voltage	-MRR -SR	Radial basis function network (RBFN) was quit equivalent with back propagation network (BPN) for prediction.
2010	Thillaivanan et al[16]	-Steel 340C	-Tungsten	-Current -Feed rate	-Total machining time	Total machining time was considered by using feed forward-back propagation neural network. The objectives were to machine over size and taper of a hole by EDM.
2011	MahdaviNejad et al[17]	-Refel Sic	-Copper	-Current -Pulse on time -Pulse off time	-MRR -SR	Back propagation algorithm was used to model the process. NSGA-II was used to optimize the response variables.
2011	Yahya et al[18]	-High strength steel	-Copper	-Gap current -Pulse on time -Pulse off time -Sparking frequency	-MRR	Significant factors were concluded by predicted values with experimental values by artificial neural network.
2011	Joshi et al[19]	-AISI P20 mold steel	-Copper	-Current -Discharge duration -Duty cycle -Break down voltage	-MRR -TWR	NSGA-II and ANN process model were considered to get optimal process parameters for finishing operation.
2012	Bharti et al C.[20]	-Inconel 718	-Copper	-Shape factor -Pulse-on-time -Current -Duty cycle -Gap voltage -Flushing pressure	-Tool electrode lift time -SR -MRR	0.67 error was concluded in the experimental result by comparing the experimental values and predicted values generated by ANN.
2012	Atefi et al[21]	-DIN 1.2344	-Copper	-Current -Pulse voltage -Pulse on-time -Pulse off-time.	-SR	A hybrid model was considered with combination of the statistical analysis and ANN model. These model were considered to reduce the error percentage.

2013	Bhavesh Patel et al[22]	-AISI H13	-Copper	-Voltage -Peak current -Pulse on time -Pulse off time -Electrode material	-SR -TWR -MRR	Levenberg-Marquardt was considered as the training algorithm which have more efficient for modelling process.
2013	Andromeda et al [23]	-steel	-Copper	-Current -Pulse-on-time -Pulse-off-time -Sparking frequency	-MRR	Predicting of MRR by using artificial neural network. 19 data were selected and Levenberg-Marquardt was used for weight update.
2013	Tzeng et al[24]	-JIS SKD 61 steel	-Copper	-Current -Voltage -Pulse-on-time -Pulse-off-time	-MRR -TWR -SR	Back propagation neural network with GA values compared with the regression models based on the RSM method. Better prediction values were attained by ANN and GA than RSM regression equation.
2013	Agrawal et al[25]	-Steel	-Copper	-Peak current -Pulse on time -Pulse of time	-MRR -TWR	ANN model was reliable and adequate to predict the TWR with negligible prediction error.
2014	Ranjan Kumar Ghadai et al[26]	-Steel WP7V	-Copper	-Current -Machining time	-TWR -MRR	With rise in current factor high MRR was attained. Due to generation of the compression shock waves it develops the rise in the temperature of the material.
2014	Balasubramaniam et al[27]	-Al-SiCp metal matrix composite	-Copper -Brass -Tungsten	-Current -Pulse-on-time -Flushing pressure	-MRR -TWR	In the investigation current was preferred as the most significant factor. Copper yield better performance than the other electrodes.
2014	Dragan et al[28]	-ASTM A681	-Copper	-Current -Pulse duration	-SR	Comparison of Fuzzy logic and neural network for modelling which results that ANN gives more accurate predicted values in EDM.
2014	Yunn-Shiuan Liao et al [29]	-Ti6Al4V -SUS304	-Brass	-Work Material -Discharge on time -Discharge off time -Arc on time -Arc off time -Servo voltage -Wire speed -Flushing pressure	-Abnormal ratio -Groove width -Machining speed -Surface roughness -Spark frequency	0.5 As learning rate and 0.5 as momentum of coefficient was considered in neural network. For the optimization GA approach was performed. With the GA technique combination of the machining parameters were successfully achieved.

2014	G. Ugrasen et al [30]	-EN31	-Molybdenum	-Pulse on -Pulse off -Current -bed speed Machining time	-MRR -SR -Accuracy	ANN function performed better predicted results than MRA and GMDH

Table: 2.1- Specific analysis performed in EDM by ANN

III. CONCLUSIONS

It is observed that different types of performance parameters are applied by different authors using artificial neural network (ANN) for the optimization of the performance variables and response variables. It is found that different types of optimization techniques are used to optimize the machining parameters in electrical discharge machining (EDM). The research work mostly use single objective approach but for high optimization and for good machining efficiency multi objective approaches are used. Artificial Neural Network (ANN) is one of the multi object approach technique used in it. Mostly research work carries out the Material removal rate (MRR), Tool wear rate (TWR), Surface roughness (R_a), etc. for different types of work material. But some performance measure like power consumption, Micro structure analysis, Heat affected zone (HAZ), hardness, dimensional analysis deviation, etc. are not explored. So this part yet to be explored.

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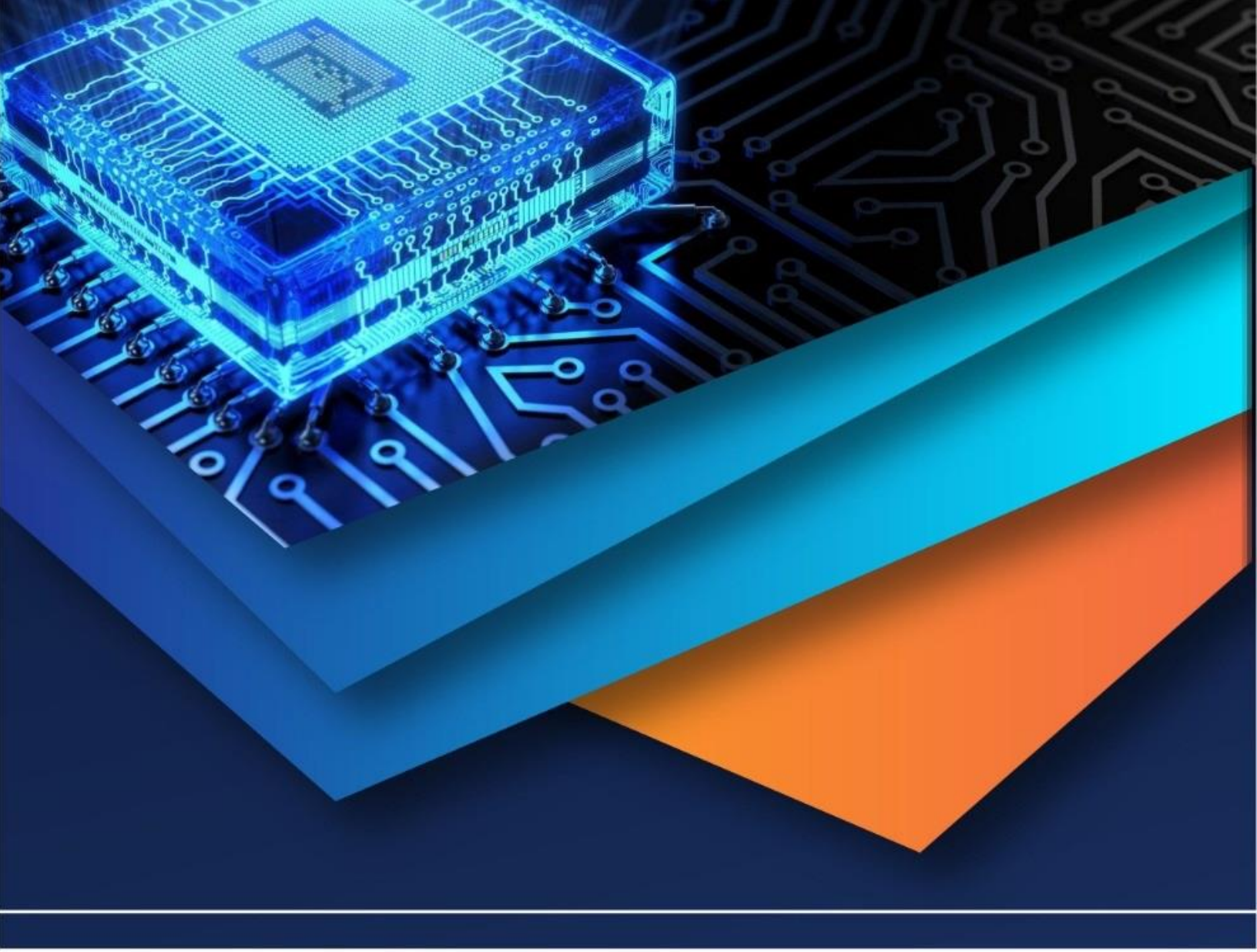

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