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A Survey on Current Research Trends in Electro Discharge Machining and Their Performances on MRR, TWR and SR

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ABSTRACT

Electrical Discharge Machining (EDM) is one of the most primitive unconventional machining processes. The potential of machining complex features giving exclusive dimensional accuracy in hard and difficult for cutting material ends up EDM process as an unavoidable and one of the most well-liked non-conventional machining process, both wire EDM and micro EDM processes are being utilized expansively in the area of mould manufacturing of dies, cavities and complex 3D structures utilizing intricate for cutting materials and its composites. The purpose of this paper is to contribute a concise statement about the troubles and challenges in the vicinity of conventional and micro- EDM, tools used for optimization and importance of combining of various predictions and optimization of tools have been discussed. A review of the upcoming research directions depend on the reassess is offered at the concluding section.

KEY WORDS: EDM, MRR, SR, TWR, ROC.

1. INTRODUCTION

EDM is currently a notorious process predominantly utilized in precise machining intricate contoured work pieces, as a substitute to supplementary conventional techniques and for particulars relating to the physical phenomena intrinsic to this process. In manufacturing technology speedy advancement has inspired the relevance of Non Traditional Machining (NTM) processes not only in up to date machining to cost effectively machine materials which are typically complicated to be machined using conventional tools. EDM is investigated involving a range of researchers.They executed the process parameter optimization of dissimilar types of EDM at various point time utilizing dissimilar optimization models and solution techniques. A considerable amount of works were paying attention on approach of producing optimal EDM performance actions of high MRR/low SR. This section provides a study into each of the performance measures and the scheme for their enhancement. In earlier period, noteworthy enhancement was performed in enhancing accuracy, productivity, versatility and safety of EDM process. Main concern is to make a choice from the process parameters namely I_p, $V_{d,}$ T_{on}, T_{off} and, P_{oil}, dielectric fluid, polarity by the approach that not only MRR increases but also the accuracy; and at the same time ROC, TWR and SR should diminish. The summary of those past studies were highlighting the objective functions, variable bounds, constraints, decision variables, remarks and their limitation. Outcomes have been summarized as follows.

Moser (2001) EDM, an exceedingly built up technology that depicts around 7% compared to all sales of other machine tool across the globe. EDM can be applied in a very extensive choice of operations together with the production of moulds and dies, production of aero engine component, surface alloying, surface texturing of steel rolls, production of aero engine components, and production of components for electronic industries and production of metallic prosthesis.

EDM is a NTM process. In this process, oil based dielectric fluid is used. Dry EDM (DEDM) is used in EDM where ecofriendly gaseous medium replaces liquid dielectric. The wastes from this dielectric are highly toxic and are impossible to be recycled. During machining toxic fumes have been because of chemical breakdown of mineral oil during heating. It need extra care when use oil as dielectric fluid, because there is a chance for fire accident. For advanced technology, the dielectric fluid altered by gases which is safety and more beneficial. The velocity gas which flows into the gap removes the impurities and eliminates over heating of the tool and work piece. For maintaining the stability in the gaseous medium it needs rotational motion in the tool. High velocity gas is entered in to the discharge gap using tubular tools. When the tool rotates it flows with a greater velocity.

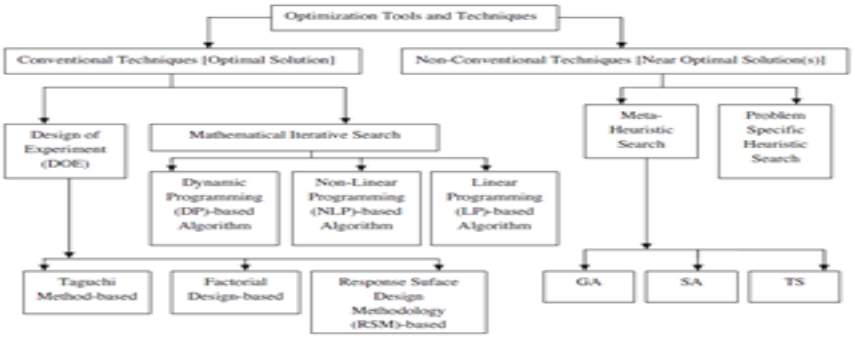

Fig. 1. Conventional and Non-Conventional Optimization Tools and Techniques

Norfadzlan Yusup (2012), in metal cutting processes, an evaluation on the optimization techniques focus on (i) modeling techniques and (ii) conventional and non-conventional (evolutionary) optimization techniques as depicted in Fig.1. Ramani (1985) in DEDM, helium and argon gas was used as dielectric medium. But, when oxygen is used as water based dielectric medium the MRR improves a lot.

Kunieda (1991) discussed the use of air as a dielectric medium. High speed gas jet used as a dielectric which was passed through thin wall tubular electrode. Further experiments in this field gave out some of the important characteristics of the process.

Literature Survey: A review of the available literature regarding EDM shows the type and extent of work done earlier, and the unexplored areas left thereafter.

EDM Performance Measures: Yu (2004) demonstrated the effectiveness of DEDM method in machining of cemented carbide. DEDM performance was compared to oil EDM milling and die sinking EDM. Gas discharge milling produces the smallest form deviation due to very low TWR is observed. The machining speed in DEDM is higher than for oil milling EDM but lower than oil die sinking EDM. However, it was argued that the total time required for making multiple electrodes in die sinking EDM puts it at a disadvantage to DEDM milling. Fewer tool electrodes are required in DEDM due to lower TWR. The total machining time for DEDM may then be lower than die sinking EDM.

Wang and Tsai (2001) presented to achieve higher MRR in EDM, demands a steady machining process, where contamination influences in the gap among the work piece and the tool, and eroding surface size also affects its specified machining command.

Valentincic and Junkar (2004); and Jaharah (2008) investigated MRR, TWR on AISIH13 tool steel. I_p was found to be the major factors which influence MRR. Higher MRR was obtained with high I_p, medium T_{on}, and low T_{off}. However, smaller TWR was obtained at high I_p, high T_{on}, and lower value of T_{off}.

Kanagarajan (2008) used electrode rotation, T_{on}, I_p, and dielectric Flushing Pressure (FP) to study MRR on cobalt cemented carbide/tungsten carbide and shown experimentally that I_p and T_{on} are the most significant factors.

Kuppan (2007) presented a mathematical model in deep hole drilling for MRR of Inconel 718. The investigation were planned to model the same using Central Composite Design (CCD) and Response Surface Methodology (RSM). Duty factor and peak current influences the MRR to a great extent and the process parameters been optimized to higher MRR through the specified Ra value utilizing the technique on desirability function approach.

Puertas (2003) realized the effect of EDM parameters on electrode wear and MRR in the work piece containing cobalt bonded tungsten carbide. For each response a quadratic model has been built up for MRR, the most influential factor known as current intensity was tracked by the T_{off}, T_{on} and the interaction effect between the opening two. The value of MRR was maximized, later then intensity of current and T_{off} were maximized and minimized by means of T_{on}.

Khan (2009) discuss the performance (MRR and TWR) of EDM mild steel with the configuration of shape in the electrode. Round electrodes exhibit maximum MRR subsequent to triangular, diamond shaped electrodes and square. On the other hand, the uppermost EWR have been identified for the diamond shape electrodes. The simulation algorithm was greatly depending on spark gap, MRR and TWR. Subsequently Khan (2008) reported on the whole functioning assessment against not only copper but also electrodes like brass and observed that the maximum MRR being seen while machining aluminum involving brass as electrodes. Electrode material like brass having comparatively low heat conductivity and almost all the heat energy was made use in the material elimination from aluminum work piece at a low melting point. Dhar (2007) estimates the consequence of T_{on}, I_p and V_d as an input TWR, MRR and S_g as a output response EDM of Al-4Cu-6Si alloy-10wt. % SiC_P composites. The second order nonlinear mathematical model was established for exhibiting the association between the various parameters in machining. The S_g, TWR and MRR are shoot up with raise in T_{on} and I_p have been observed. Salonitis (2009) established an easy temperature based model to calculate the MRR and state that the rise of I_p, T_{on} or V_{on} results in greater MRR, besides, MRR increases with the reducing T_{off}. They reported that model predictions and experimental results are in good agreement.

Taweel (2009) reported the process parameter correlation in EDM of CK45 steel with Al-Cu-Si-TiC composite generated involving powder metallurgy technique and analyzed TWR and MRR. Chiang (2008) had demonstrated the influence of V_{on}, I_p, T_{on}, and T_{off} on the reaction of EWR and MRR. The investigations are planned according to a CCD on Al_2O_3+TiC work piece and the parameters influences and implementing ANOVA communications were researched. An advanced mathematical model was introduced and alleged to predict and fit MRR perfectly showing confidence level of 95%. The most important features that affect the reaction were T_{off} and I_p.

Dvivedi (2008) found the performance of machining in terms of TWR and MRR by getting a setting of T_{on}, T_{off}, I_p, and FP that is optimal, during EDM having the Metal Matrix Composite (MMC) of Aluminum 6063 SiC_p. I_p

was predominant on MRR when comparing with parameters of additional importance has been realized. MRR value boosts up with rising of T_{on} and I_p to an optimal point then its stopped. Karthikeyan (1999) built up a mathematical model for optimize EDM characteristics like MRR, TWR and the SR on Aluminum silicon carbide particulate composites, using Full Factorial Design (FFD).

Wang (2009) experiment the optimization and feasibility of EDM for checking the machinability composites such as W/Cu using the Taguchi Methodology utilizing L_{18} orthogonal table to obtain the polarity, I_p, T_{on}, T_{off}, rotary electrode planetorial speed, and V_d to explore the TWR and MRR. The tool wear is moderately analogous to the MRM in EDM. Mohri (2009) ascertained that during sparking precipitation take place and it affect the tool wear due to the precipitation of turbo static carbon in the hydrocarbon dielectric on the electrode surface.

Marafona and Wykes (2002) used energy dispersive X ray analysis of tool surfaces measuring their compositions and established. There is a noteworthy enhancement in TWR due to the thickness of carbon inhibitor layer; it has small effect on the MRR. Mohri (2000) and Bleys (2002) devised an online tool wear compensation method depends upon the pulse analysis and controlled the tool's lively feed movement.

Kunieda and Kobayashi investigate the TWR ratio by spectroscopic calculation of the vapour density of the tool electrode. Longer T_{on} has been well known for resulting in lesser TWR and a thicker layer deposition of carbon on the surface of the tool electrode.

Snoeys (1986) explained that he well known machining strategy of recompense the tool wear was the orbiting of the electrode in relation with work piece, where a rotationary motion creating an efficient flushing action, get better accuracy and efficiency in the process. Staelens and Kruth (1989); and Yu (1998) reported a uniform TWR machining technique to compensate the longitudinal TWR by performing to an extended beyond forward and backward machining movement.

Dauw and Snoeys (1986) estimate the calculation of TWR by the characteristics of pulse based upon V_d fall time. The analogous TWR compensation approaches are functional to micro EDM is usually implemented in layers that are thin which use tubular or simpler cylindrical electrodes. On the other hand, Kunieda and Yoshida (1997) reduced the TWR by performing µEDM using high velocity gas as the dielectric medium. Various types of simulating the EDM also offers tremendous prospect of considerate and compensate the TWR.

Dauw (1988) introduced geometrical simulation of EDM demonstrating the growth of part geometry and tool wear. Caydas and Hascalik (2007) prepared an effort to analyze the electrode wear in EDM of Ti alloy utilizing statistical analysis technique. ANOVA and regression analysis were done, the aimed mathematical models obtained are often discuss the performances of factors within the limits are studied. ize and gap voltage, which vary with the amperage used. Narender Singh (2004), described when low diameteral ROC is the requirement EN31 may be preferred over copper and aluminum electrodes. CNC EDM commonly makes use of 3D profile electrodes that are too expensive and time consuming to production for EDM process.

Wong and Noble (1986) experiment and researched the machining materials by means of microcomputer controllers and cylindrical electrodes. Kunieda and Masuzawa (1988) developed a number of electrodes discharging system which delivers additional discharge simultaneously from the respective electrodes that are connected serially.

Kunieda (1999) presented oxygen combined EDM system, which largely improves MRR and examined by providing O_2 into the discharge gap, beyond MRR can be improved with decreased TWR using a multiple electrode discharging system using without any improvement in SR. McGeough and Rasmussen (1997) study a mock up for the effect of dielectric fluid based on electro discharge texturing and in only the influence of variation in the dielectric resistance throughout single voltage pulse. The speculative expectations authenticate the realistic estimations which SR in texturing is calculated initially using the length of the voltage on time and peak current used. Cogun (2004) researched under changing machining process parameters applying over profile surface of 2080 tool steel machining. SR rises with rising I_p, T_{on} and P_{oil} has been observed. Surface profile data obtained was transmitted to computer, digitized and modeled later in Fourier series.

Perez (2004) gave a suitable form to calculate comparative power dissipation by means of considering the characteristics of cathode space charge and various current emission mechanisms which was suitable for refractory and non-refractory materials. Tantra (2006) examined the lifetime of model introduced by Heuvelman to wear down the material's hardness for expecting tool wear and its usability for EDM process like deep holes drilling of turbine blades from the research outcomes. It shows that the Heuvelman model would not contribute a straight association along the examination.

Samesh Habib (2009) has analyzed the effects of machining parameter like I_p, T_{on} and V_d on TWR and MRR in EDM using RSM. TWR and MRR value is maximized by means of maximizing parameter values. Chattopadhyay (2009) utilized Taguchi`s DOE technique for conducting experiment on planetory EDM copper and utilizing EN8 steel as a combination in the work piece tool and introduced experiential relation with the performance uniqueness (MRR and EWR) and process parameters like I_p, T_{on} and rotational velocity of tool electrode.

Workpiece and Tool Materials: Advanced investigated presented here was related to the EDM of AISID2 steel, it was greatly developing range of application in mould and dies making industries. Lee (1988) reported that constant flushing and dielectric condition, for a choice of I_p levels unstable from 5 to 25A, the white layer compared with the pulse energy not correspondingly to the steel material of tool was observed; however the white layer's magnitude relies merely on the size or area of the current pulse form excluding the shape of it.

Guu and Hocheng (2001) investigated the parameters influence of a planetary EDM like rotation of work piece on MRR and SR and T_{on}, rise on rise of rotational speed has been observed. Also, the results were compared with the conventional EDM and found to more MRR, improved SR and reduced recast layer.

Guu (2003) reported that a Heat Affected Zone (HAZ) has been shaped just underneath the layer of recast and introduces tensile residual stress on the surface owing to the heterogeneity of heat flow and metallurgical transformations or to localized inhomogeneous plastic deformation. Subsequently, with experimental analysis, Guu (2005) investigated the surface morphology, micro crack of EDM AISID2 tool steel and SR use the Atomic Force Microscope (AFM) and possessions which the factor namely release energy, that concludes the surface texture.

Marafona and Araujo (2009) have reported their research on effect of the work piece hardness but, they did not provide conclusive result that hardness significantly affect MRR. They suggested that the interaction of work piece hardness with various factors may be responsible for variation in MRR. Whereas, the SR obtained is marginally influenced by work piece hardness.

Pradhan (2009) have presented a RBF and prediction of SR using BPN network model. The input parameters used for this investigation were I_p, T_{on} and duty fraction and both the models could predict SR with reasonable accuracy. However, RBF was faster and the back propagation is reasonably more accurate model. Further, Pradhan (2009) presented a second order regression model and ANOVA was implemented for testing the model's adequacy of the model and compared with the RBF and a BPN models.

Pradhan and Biswas (2009), a regression model and a neuro fuzzy model was introduced for predicting MRR, experiments were done with different levels of I_p, duty fraction and T_{on}. The predicted models were compared and absorbed that the neuro fuzzy model has better predictive ability when compared to the regression model.

Yan-Cherng Lin (2008) this investigation result shows with the aim of maximized MRR along the electrical discharge energy density. Machining impurities diameter and EWR are associated with electrical discharge density. Lee and Li (2001) investigated in EDM the parameter's effect of tungsten carbide. In tungsten carbide for better performances electrode acts as the cathode and the work piece acts as anode. Negative sign tool provide high MRR, low TWR and better Ra.

Puertas and Luare (2004) conductive ceramic materials like boran carbide calculate some of the significant characteristics such as MRR, SR and TWR. Wang and Lin (2009) describe the W/Cu composite material optimization that is utilized in the Taguchi Methodology. The L_{18} orthogonal array and Taguchi Method are used to attain the T_{on}, I_p, duty factor (T_{au}), V_d, polarity and rotary electrode rotational speed to explore the MRR, SR and EWR.

Tsai (2009) possess working material of copper alloys, graphite and copper are commonly involving EDM. Excellent thermal and electrical conductivity and high melting temperature are the characteristics of these materials. This investigation make known the composite electrodes got high MRR and Cu metal electrodes.

Surface Integrity of EDM: The surface integrity is used to define the condition and quality of the surface region of a machine component. It includes the mechanical, chemical, metallurgical, topological conditions of the region of surface as well as the structure of surface and sub-surface.

Rajurkar and Pandit (1988) established that EDM surfaces usually experiences a transformed or altered layer having different characteristics from those of the parent metal. A wide-ranging explanation of integrity of surface of EDM components necessitates the measures of SR, WLT, HAZ, micro cracks, and residual stress, diffusion of tool material and carbon, and endurance limit.

Cogun and Savsar (1990) developed the thermal changes may cause cracks in the top layer and residual stresses in the underlying base layers accuracy.

Kruth (1995); and Schumacher, (2004) find EDM has many advantages but, the recast layer with cracks, caused by rapid cooling results in poor surface. Surface texture, surface topography or Ra are the terms, which are used to express the machined surface relate to the geometric irregularities and to quality the surface.

Pandey and Shan (1980) described EDM surfaces consist of plenty of craters formed by the discharge energy. If the energy content is high, deeper craters will be accomplished, leading to poor surface. The SR has also been found to be inversely proportional to the frequency of discharge.

Pandey and Jilani (1986) showed spark eroded surface is a surface with a matt appearance and random distribution of overlapping craters and is often covered with a micro cracks network. Formation of crack has been correlated between the greater heat stresses development in the material and also with plastic deformation.

Kiyak and Cakir (2007) analyzed the influences of process parameters in Ra for EDM machining of AISIP20 tool steel and emphasized that the choice of the machining parameters to achieve good surface quality of EDM

component should be minor pulsed current and shorter pulse time which is due to; less crater depths and size of particle created by discharge and consequently, the smooth surface will be produced.

Keskin (2006) in this work it is revealed that Ra increases with a rise in T_{on}, which is probably because of more discharge unconfined at this time and expands the channel discharge.

Khan (2009) discuss the SR performance of EDM mild steel for different shape configuration of the electrode. Round electrodes exhibit minimum SR subsequent to triangular, diamond shaped electrodes and round.

Tsai and Wang (2001) reported several Ra models by accounts the effects of electrode sign. They frequently reported a partly experimental model rely on the electrical, physical and electrode's thermal properties and work piece are combined together with the relevant parameters like input power, polarity, I_p, T_{on}, specific heat capacity, heat conductivity, material density, conductivity, boiling point and melting point.

Tsai and Wang (2001) reported the later model was found to be a more trustworthy Ra prediction for various work piece materials (EK2 and H13) under various process conditions. Ekmekci (2007); and Mamalis (1988) reported the surface of material is seen to be a better challenging to etched by traditional metallographic reagents. Therefore, the ferrous alloys in the recast layer are called as an unetchable damage layer. Micro hardness calculations have seen in the recast layer normally possess a high hardness value than the underlying matrix and it might surpass the achievable by usual quenching methods.

Lim (1991) in his work HAZ lies beneath the white layer structures, which normally has a strengthened microstructure and possess a hardness value rather not as much of the underlying hardened metal. An intermediary layer with the recast and the strengthened layers have been also noted and reported.

Lee (2003) showed that the structural change of EDM surface have been studied extensively revealed experimentally that the persuade of the EDM parameters on the surface integrity of AISI1045 carbon steel and furnished that average WLT and residual stress that is induced leads to rise at greater values of I_p and T_{on}.

Lee and Tai (2003) the study indicates correlation linking EDM parameters and formation of surface crack for D2 and H13 tool steels. Crack formation and WLT is correlated to the machining parameters has been shown. High T_{on} will shoot up together the WLT and the induced stress and both of them tend to support the formation crack. Bhattacharyya (2007) introduced a mathematical model for RSM in correlating I_p and T_{on} dissimilar feature of surface integrity of M2 die steel machined via EDM at the transverse section of the EDM M2 die steel and experimentally validated using the SEM micrographs and the graphs plotted and disclose the rightness of the built up models.

Rebelo (1998) have reported Penetration depth and density in the recast layer rise with the machining of pulse energy. Ramasawmy (2005) experimentally investigated I_p has comparatively more significant influence over the crater dimension as assessed against T_{on}.

Mamalis (1987) in their experimental study revealed that "White Layer" and formation of crack have been related along the development of greater thermal stresses more than the material's fracture strength additionally to plastic deformation and are calculated quantitatively using the equations of regression; it is clearly shown that their dimension depend on pulse energy.

Wang (2009) studied the viability of eliminating the recast layer from moulds furthermore dies use mechanical grinding and etching for Nitrogen dependant super alloy materials by EDM.

Thomson (1989) in this study crack development can be accredited to the existence of not only thermal but also tensile stresses within the EDM component. Tensile stresses are produced since the material which was melted contracts more than the unaffected parent material.

Results from previous studies Lee (1992; 2003) pointed out that increase of crack as the pulse energy shoot up. But, it was defined that increased crack density usually occurs under the decreased I_p and increased T_{on}. But, it was defined that increased crack density normally occurs under the decreased I_p and increased T_{on}.

Lee (1996) presented EDM of H13 and D2 tool steels and analyzed the concept of a Crack Critical Line (CCL) is introduced for exploring the effect of electrode size, EDM parameters and material thermal conductivity on surface cracking. It is noted that cracks tend not to appear when the machining is performed with a decreased I_p and an increased T_{on}.

Zeid, (1997) investigated the mechanical components fatigue strength was depends upon the characteristics of the near surface and surface regions. Cracking was found commonly in the surface defects since it tends to a deduction in the material resistance to corrosion and fatigue.

Ekmekci (2006) reported Residual tensile stress rises along the rise in pulse on duration and pulse current. Experimentation of the stresses which is residual in EDM components exposed their character of tensile, the very slender superficial zone that they emerge, their higher magnitude at the surface layers, and their rise with rising pulse energy. Ekmekci (2005) presented a qualitative relationship along the parameters of operation using AISIP20 work piece material.

Mathematical Modeling: Several modeling methods are made to characterize the EDM based on electro thermal theory since 1971. Many researchers has analyzed with regard to temperature distribution, material removal at the

cathode and crater geometry. Yeo (2008) showed that the disk heat source models could be better on improvising the of the heat flux approximation and energy fraction, however, a simple cathode erosion model utilizing a point heat source model.

Eubank (1989) demonstrate a cylindrical plasma model with differential mass was created sparks which contains differential equations in three numbers, individually taken commencing energy balance; radiation equation and fluid dynamics are united to a state known as plasma equation.

Later Sen and Shan (2007), Gao (2008) pursued the related technology in optimizing and modelling EDM process preferring to pair various work tool material.

Tolga Bozdana (2010) report an investigational analysis on EDM in drilling 2mm diameter holes on Inconel718 with brass as an electrode. The process parameters effect (I_p, T_{on} and T_{off}, and capacitance) on outputs (MRR and TWR) was calculated rely on restricted amount of experiments.

Ghanem (2003) encompass analyzed on martensitic non hardenable and hardenable steels and explained a wide profile and a large tensile stress level are combined with surface stress relaxation for hardenable steel. Simulation of the mechanical effect because of the gradient of heat encouraged by the electric discharge (thermal and residual stresses) is the purpose of even smaller amount numerical latest studies where normally commercial codes have been utilized.

Dibitonto (1989) demonstrated an easy erosion of cathode model and this uses the technology called photoelectric effect. It is the dominant energy source provided to the surface of cathode. Selc (2006) shown the influence of V_d, I_p, T_{on}, pulse interval, P_{oil} on MRR, SR and TWR of process EDM utilizing the work piece such as Tungsten Carbide (WC) and copper tungsten as electrode (CuW). WC is suitable for EDM tool material and there exist an optimal circumstance in precision machining of WC even though the situation possibly differs with composition of material has been observed.

Pradhan and Biswas (2009) have adopted RSM design to conduct experiment on EDM and developed the effect of four input variables such as I_p, V_d, T_{on}, and T_{off} on machining performance utilizing copper and AISID2 steel as tool grouping of work piece. T_{on} and I_p have considerable consequence on SR is noted.

Helmi (2009) had investigated SR and MRR in EDM process employing Taguchi Method while tool steel was machined using copper and brass electrodes. It is noted from analysis of variance that pulse on perfect instance and peak current were mainly noteworthy factors influencing the performance characteristics.

Prabhu and Vinayagam (2010) have experimentally explained the micro cracks and SR on AISID2 tool steel are substantially decreased when the tool (electrode) is encrusted using a carbon nano tube layer.

Kansal (2005) developed the RSM optimization method to choose the process parameters in the powder assorted EDM. In solving multi optimization difficulty in EDM, Lin (2006) used GRA based on fuzzy based Taguchi Method and orthogonal array.

Sameh (2009) illustrates the improvement of a wide ranging numerical model in correlating the higher order manipulation and interactive of different EDM process parameters are passed via RSM, involving appropriate experimental value as acquired via conducting tests.

Majumder (2012) present investigation on the parameters of EDM process were optimized for minimum EWR. The relation between EWR and machining parameters has been developed by using RSM.

Sushant Dhar (2007) effort assessess the consequence of T_{on}, V_d and I_p on, TWR, ROC, MRR on EDM with Al–4Cu–6Si alloy–10 weight % SiC_p composites. The three factors and three levels FFD was developed to analyze the solutions.

Numerical Modeling: Several approach for solving the thermal problem are enumerated and comprehensive evaluation of mathematical models for EDM was provided Erden (1983), but at the present time the majority of investigation is passionate to models that are numerical depend either on the FEM or in the finite technique of differences.

Yadav (2002), FEM model was brought up for approximating the heat field and heat stresses because of Gaussian heat flux distribution belonging to spark for the period of EDM of HSS material. The effects of process variables such as (I_p and T_{off}) on these responses have been reported.

Nizar Ben Salah (2006) demonstrated numerical results relating to the thermal sharing in EDM process and with these outcomes of temperature, SR and MRR have been inferred and assessed against explanation towards experiment. Marafona and Chousal (2006) developed a thermal electrical model using copper and iron as anode and cathode sparks produced by electrical discharge in a fluid media and the obtained FEM outcomes have been assessed against the investigational values of the table utilized by various researchers.

Allen and Chen (2007) reported a thermo numerical model for material removal on molybdenum by a single spark, the influence of EDM parameters on the crater dimension and the tool wear percentage have been learnt.

Das (2003), FEM base model was reported using process parameters namely power input, pulse duration, etc., for estimating liquid and solid state material transformation, the transient temperature distribution and residual stresses influenced in L6 steel.

Soft Computing Modeling: Mahdavi Nejad (2011), presented the work is aimed in optimizing the MRR and SR of EDM of SiC parameters concurrently. ANN and BPN algorithm together in association was implemented to process the model. Non Dominating Sorting Genetic Algorithm II (NSGA-II) and the MOO methodology were utilized of optimizing the parameters of process. The three significant consequences of input process parameters namely I_p, $T_{off,}$ T_{on} EDM of SiC are taken. Experiments are performed over a huge choice of preferred input parameters to train and verify the model.

Hari Krishna (2011), work is utilizes two computational methods that is ANFIS, modeling and ANN to expect Ra of work piece for various machining conditions in hard turning. These models are adopted to capture the desired parameters and predict Ra. Tarng (1997), in EDM, adopted a fuzzy pulse discriminator in dividing different discharge pulses. The Simulated Annealing (SA) algorithm plays a role in developing the particular membership function. Trapezoid membership function has also been seen appropriate in adopting fuzzy pulse discriminator that is not only rapid but also accurately divided the discharge pulses underneath different machining conditions.

Wang (2003), presented a cross GA and ANN methodology to optimize and model the EDM process. Yilmaz (2006), developed Defuzzification methods, Fuzzy expert rules (if–then rules) and functions involved in membership help to remove the difficult situation. Seeing that a conclusion, a supplementary fine choice of EDM complex parameters to calculate is considered in account was entered via the adopted fuzzy model.

Zhang (2002), demonstrated an adaptive fuzzy control system to EDM giving ultrasonic vibration. The gap and the discharge pulse parameters with the work piece material and tool electrode have been restricted the system in an appropriate manner.

Salman and Kayacan (2008), represented the work piece (cold work tool steel) SR then EDM utilizing the Genetic Expression Programming (GEP), an Artificial Intelligence Method (AIM) I_p, T_{on}, T_{off} and S_g are involved to be the model parameters. Kaneko and Onodera (2004), use a simple fuzzy deduction having input signals of two like frequency of arcing and short circuit for a die sinking EDM to develop the cutting performance. A tremendous development in machining velocity and the maximal deepness of machining cut has been obtained via approaching motion of the electrode tool and controlling the jump heights.

Tzeng and Chen (2007), implemented a FL analysis with Taguchi dynamic analysis in optimizing the fine quality and efficiency regarding to high velocity EDM process. The order of the significance of each factor and the conditions of optimal machining was calculated utilizing not only FIS but also ANOVA techniques correspondingly. Lin and Lin (2005), used GRA was based on Taguchi Methodology that was fuzzy based and using the processed named multi response, orthogonal array is involved to optimize the EDM process. Seeing the result, SR, MRR and EWR within EDM are highly developed implementing these methodologies.

Hybrid Tools: Erden (1995), several approach for solving the thermal problem are enumerated and comprehensive review of mathematical models for EDM, but at the present time the majority of investigational work is passionate for the numerical models based on either the finite differences method or Finite Element Method (FEM).

Mandal (2007), developed the BPN. TWR and MRR were optimized by NSGA-II. Beginning the literature review, AI techniques including FL, ANN, Taguchi based fuzzy systems and grey relational holds extensive choice of applications in restricting the EDM components of the system and model of the process parameters have been noted. ANFIS known as a hybrid model integrates both the ANN and FL method.

Jang (1993) used the numerical properties of ANN the rule based fuzzy systems estimated the human process data, involving two paradigms ANFIS harnesses the power: ANN and FL. It prevails over its possessing shortcomings concurrently. Wang (2003), exhibited GA with ANN was used to develop the process parameters for developing the performances in EDM process using graphite as tool and nickel based alloy as work piece. Both case studies were developed by Tarang (1988); and Reddy (1997) solved utilizing the planned technique and the solution gave an excellent result for multi response problems. Antony (2006) have used Taguchi design and proposed an ANFIS for instantaneous optimization of numerous responses. A BPNN with Levenberg-Marquardt (LM) algorithm have projected by Panda and Bhoi (2005), for the prediction of MRR. Recently, SA technique with ANN approach has been used for optimization of MRR and SR.

Shabgard (2009) exhibited that the regression technique are productively used in modeling the output and input variables of EDM of WC–10%Co. Lin and Han (2006) developed the evaluation concerning tube electrode to drill using EDM comprises a stabilizer block and a mover. Tsai and Wang (2001) established seven models in order to predict the Ra of work and MRR in EDM process and compared based upon six NN and an ANFIS with relevant machine process parameters agreed by the DOE technique.

Mpofu and Tlale (2012) functional an efficient technique which incorporates multi-level fuzzy decisions in generating the dynamic optimal configurations for machine structures confirming to the specified geometry of the part that represented the usage of fuzzy decisions to model the configuration system.

Liao (1996) investigated into fuzzy multi criteria decision making methods that adopted to help for choosing the material decisions in engineering design field. This method firstly calls the decision maker and designer to give the required data on applicable material characteristics, the corresponding specified data, and weights as well.

Input and output associations of an EDM method were recognized not only in forward but also in reverse directions incorporating ANFIS by Maji and Pratihar (2010) Three input parameters, such as I_p, T_{on}, two outputs and pulse-duty-factor namely, MRR and SR were taken into account for the above-mentioned mappings. Also, an Adaptive Control Optimization (ACO) system was enhanced by Sivapirakasam (2011) studied a grouping of fuzzy and Taguchi technique to resolve multi response parameter of the process to optimize difficulties in green production EDM. The output responses for the weighing factors were calculated by using triangular fuzzy numbers. The model brought up in this research could be utilized as a systematic framework for optimizing the parameter in environmentally aware manufacturing processes.

Kao and Shin (2008) utilized the alteration of a three input FL controller and design for EDM of diesel injector spray holes. A fuzzy rule dependent system is developed for better and user friendly selection of EDM and processes machining parameters. Garcıa Navasa (2008), EDM be an replacement method in hard turning and grinding in the cutting of tool steels therefore EDM permitting machining of several variety of conducting material, unless of its hardness. Furthermore, supplementary factors have got to be well thought-out in selecting machining processes, particularly considering responsibility parts.

Seung Han Yanga (2009), suggest, in EDM and optimization method to choose the excellent process parameters. For regular cutting testing dissimilar scenarios of process parameters uses die sinking machines. This arrangement model is useful concurrently in maximizing the MRR along with minimizing the SR using SA scheme. Joshi (2011) discusses an efficient approach for optimization and process modeling of EDM. Physics leaning process modeling by means of FEM combine the soft computing techniques similar to ANN and GA in the idea of improving forecasting model accuracy holding not as much of reliance on the investigational values.

Ramezan Ali (2009) intend in optimizing the MRR and SR corresponding to EDM of SiC parameters concurrently. Unclear process parameter exists, leading to uncombined machining parameters, making available the greatest machining performance. In modeling the process ANN with BPN algorithm is considered to be utilized. Musrrat Ali (2009) design of experiment is an intelligent but easy progressive algorithm to optimize actual valued, multimodal task.

Qing Gao (2008) explains GA and ANN is combining together to setup the process parameter optimization. ANN model modifies the LM algorithms are established to perform the relationship among MRR along with input parameters as well as GA is consumed in optimizing the parameters receiving optimization results.

Krishna Mohana Rao (2010), work has been proposed in optimizing the hardness of surface generated during die sinking EDM due to the instantaneous effect corresponding to different input parameters. For M250, 15CDV6, HE15 and Ti6Al4V, investigations are carried out by changing V_d as well as I_p and the respective hardness data were calculated. Su (2004) established an ANN model and additionally it was used in optimizing the input parameters by means of GA. Thillaivanan (2010), implemented a possible technique of optimizing EDM machining parameters beneath the minimal entire cutting duration has been dependant on Taguchi method and ANN is shown. Concluding that, the functioning feature average time of machining are enhanced via this approach.

The present trend of favoring intelligent tools in the domain of manufacturing is because of its improved computing power and its ability to find the expected objectives for various inputs on detaining the genuine circumstances and utilizing them to build up a generalized model to be used in future. The intelligent tools are implemented in engineering technology to solve complex problems usually needs human intelligence, Pham (1999); and Tetir (1997) reviewed the intelligent tools for the determination of machining parameters.

Linked Simulation Optimization Model: In Linked Simulation–Optimization Model [LSOM], the models have been integrated with an optimization model that is dependent on the prediction and investigation based algorithm. In the LSOM, the data and release histories of the process parameter sources have been treated as the clear decision variables and estimated via the optimization model. Also, an implicit solution procedure has been projected for determining the optimum number of process parameter that is the model's benefit. The functioning of the aimed model is asserted and examined on EDM machining examples for easy and difficult aquifer geometries, measurement error conditions and various search solution parameter sets. Recognized solutions depict that the projected LSOM is an efficient path and hence utilized in solving the different machining problems. Researchers proposed training of NN with various search algorithm and FL, Yigit Karpat (2006); Natarajan (2006), for variety of machining applications. The development of LSOM techniques for prediction of machining quality needs attention.

III. SUMMARY

EDM has provided numerous betterment in process of machining in recent years. The competence of machining complicated parts and hard material developed EDM as one of the most well-liked process of machining. EDM contribution to industries namely cutting novel hard materials creating EDM technology stays essential. Reassessment of the research trends in EDM machining and modelling technique in predicting optimizing EDM performances are presented. The development progress in every area has been offered involving flow diagram as show in Figure 2. For every new method brought in and engaged in EDM process, the purposes remains same: for enhancing the ability of performance of machining, for obtaining improved product of output in developing method for machining novel materials and for holding improved condition towards work.

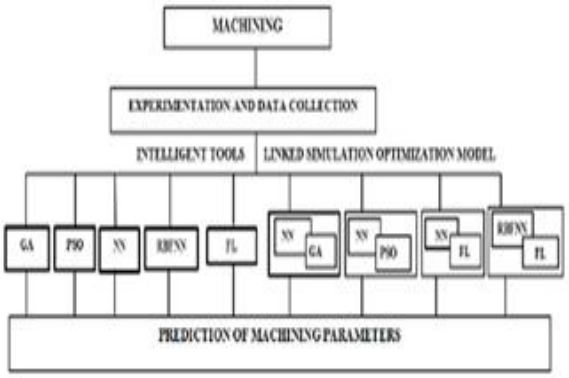

Fig.2. Theoretical Models Available in Literature for Simulating the Input and Output Parameters

2. CONCLUSION

a) EDM usage seems to be flourishing swiftly in tool rooms, die shops and also in all-purpose shop floors of recent industries for facilitating intricate troubles in machining difficult-to-cut materials and contribute improved surface integrity. Beyond a detailed inspection of the available work, the subsequent termination has been drawn.

b) Discharge current effect and pulse duration was brought into preference in numerous investigation works but disparity in pulse interval was not examined or it was brought into preference in conjunction with pulse duration involving duty factor. Necessity of independent research occurs so that the influence of this significant input parameter of process on the occurrence of MRR and SR.

c) Much of the existing research works on powder-mixed dielectric informs the impact of machining on MRR, SR and TWR etc. with polarity that is normal. The research of the impact of this technique on alteration of surface was handled by very less researchers.

d) Least amount of work was reported on tool surface of steels and aluminum based composite. Similarly, few of significant die steel materials namely OHNS die steel, molybdenum high-speed tool steels and water-hardening die steels was not tried as materials of work.

e) Fewer tool electrodes are required in dry EDM due to inferior tool wear. Total machining time for dry EDM may then be lower than die-sinking EDM which is not yet explored.

f) Various kinds of multi-objective optimization tool could assemble the necessities of the process of machining in identifying a group of solutions depending on association of appropriate variables.

g) GA and PSO based multi-objective optimization for maximization of MRR and minimization of Ra was performed by utilizing the brought up empirical models but not in metaheuristic, SVM, fuzzy, eVQ, rough set etc.

h) MRR and SR were optimized as purposes on utilization of multi-objective optimization method.

Future directions of Research: The following is a catalog shortening the upcoming research openings, challenges and strategy in the field of EDM, micro-EDM or nano-EDM of various materials.

a) Optimization of the micro-EDM of automobile and aeronautical based aluminum, copper and magnesium based composites has to be performed.

b) There have been instances where different soft computing techniques were utilized for predicting the EDM parameters. Some attempts have also been made to minimize the SR and maximize the SR. However, in order to maximize the MRR, the input current should be maximized provided to the work piece and heat affected zone remain the same. No such attempt has been reported, where this type of constrained optimization problem has been solved.

c) Betterment on Machine tool fabrication development, dimension measurements and fabricated parts accuracy.

d) Enhancement on finish over surface and steel tools, die steels and composites materials accuracy.

e) Optimization of the process named EDM and/or construction of innovative EDM dependant approaches for producing mirror SR and maximum MRR using various algorithms.

f) Not much work is conducted for EDM composite materials that are conductive. Hence, this scenario can be studied in EDM machine. For analysis and optimization, soft computing techniques like GA, FL, ACO and PSO can be used.

g) Development of advanced hybrid machining technologies and optimization tools in the idea of overcoming numerous shortcomings handled in the EDM process optimization of various materials can be carried out. Optimization and prediction tools possess the competence of associating the strength and to prevent the failing of various process/tools.
h) Literature review shows various prediction techniques with the help of intelligent tools. It is to be noted that the performance of intelligent techniques may be dependent on the number and nature of evaluation process made by the algorithm. Not much study has been reported in which intelligence techniques have been obtained along with other parameters of the techniques to improve its performance.

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