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An Overview on Process Parameters Improvement in Wire Electrical Discharge Machining

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ABSTRACT: *The dimensional accuracy and quality of the surface of the machined piece are greatly influenced by the determination of optimal range of the Wire-Cut Electric Discharge Machining (WEDM) Parameters. Numerous researchers have approached to solve this problem with experimental, analytical and numerical analysis. There is less work of the consensus on the basic effect of the Wire material on the workpiece in WEDM, even though considerable research effort has been made on it. It is staggeringly difficult to foretell in a precise manner the performance of Wire in WEDM for the dimensional accuracy and quality of the surface machined from this process. This paper reviews work on the requirements for optimization of Tool wear so that its life could easily be predicted.*

Keywords: *WEDM, Optimization, Taguchi, Surface roughness*

I. INTRODUCTION

The material removal mechanism of WEDM is very similar to the conventional EDM process involving the erosion effect produced by the electrical discharges (sparks). In WEDM, material is eroded from the workpiece by a series of discrete sparks occurring between the workpiece and the wire separated by a stream of dielectric fluid, which is continuously fed to the machining zone [Puri et al. (2003)]. Nevertheless, nowadays workpieces are totally submerged in a tank filled with dielectric fluid while WEDM process is commonly on. The efficient flushing and temperature stabilization is promoted by the submerged method of WEDM, especially in cases where the workpiece has varying thickness. The electrical energy generating a channel of plasma between the cathode and anode is ised in making WEDM Process [Shobert et al. (1983)], which is turned into thermal energy at a temperature [Tsai et al. (2003)]. This initializes a substantial amount of heating and melting of material on the surface of each pole and can occur in the range of 8000–12,000 ^{O}C [Boothroyd (1989)] or as high as 20,000 ^{O}C [McGeough (1988)]. The breaks down of plasma channel due to turning off D.C. current power supply occurring between 20,000 and 30,000 Hz [Krar (1997)] causes a sudden reduction in the temperature, which, allows the dielectric fluid to circulate the plasma channel and implore the molten particles from the pole surfaces in the form of microscopic debris.

Despite the fact, that the material removal mechanisms of WEDM and EDM are alike yet the functional characteristics are not identical. A continuously thin wire feeding through the workpiece by a microprocessor is used by the WEDM, which enables the machining to be exceptionally high accurate even when the parts have complex shapes. The gap between the wire and the workpiece, varying from 0.025 to 0.05 mm is constantly maintained by the microprocessor [Benedict (1987)].

[Kunieda et al. (2001)] conducted an experiment on WEDM in a gas atmosphere without using dielectric fluid. By their experiment they tested the feasibility of WEDM process to be conducted dry in order to improve the accuracy of the finishing operations. [Ho et al. (2004)] classified the major research areas of WEDM (Figure 1) and classified the wire-cutting EDM machine (Figure 2).

II. LITERATURE REVIEW

[J. Wang et al. (2003)] developed a method for numerical control (NC) of traveling wire electric discharge machining (EDM) operation to obtain desired cut profile in terms of its contours. The tool motion obtained is in terms of the movement of centerline of the wire and it also neglects the effects of the wire thickness and the gap distance on modeling the cut profile. They presented the tool motion generation for wire cut EDM using a technique based on boundary profiles and contours. Selected method was provided for improvements over the exiting techniques both of the computational and modeling aspects. They showed a functional diagram of Wire-

EDM system in figure 3. They also generated methods for rendering offsets of ruled surfaces was developed in the past [Ravani et al. (1991), Pottmann et al. (1996)].

[Puri et al. (2003)] worked to improve the techniques to meet the increasing demand of product, accuracy and precision in sectors of manufacturing. They found that, the machining performance was influenced by the wire tool vibrations occurring during machining operation. Their experimentation dealt with the vibrational behaviour of the wire and they presented an analytical approach for the solution of the wire-tool vibration equation considering multiple spark discharges to investigate into the characteristic effects of wire vibrations in wire electric discharge machining (WEDM). The observed the relation between the amplitude of the vibration of the wire and the state variables easily from the solution of the equation. Their further analysis showed that, the higher the thickness of the workpiece, the larger will be the maximum amplitude of vibration for a given span of the wire between the a_o and guides. They thus concluded that, minimization of inaccuracy and in precision due to wire-tool vibration will find potential industrial applications for manufacturing jobs with high-precision contours.

[Liao et al. (2004)] studied about the relationship between machining characteristics and machining parameters of different materials in WEDM which were otherwise difficult to obtain because a large number of experiments should have been conducted repeatedly. The specific discharge energy (SDE) is defined as the real energy required to remove a unit volume of material is proposed. They found that, SDE is constant for a specific material. Their experimental results revealed that, the relative relationship of SDE between different materials is invariant as long as all materials are machined under similar machining conditions. They also observed that, the Material Removal Rate was increased but the efficiency of material removal decreased with the increase of discharge on time. They showed the Variation of machining characteristics varied w.r.t. significant machining parameters in Table 1. They also concluded that, the use of characteristics of SDE, determines the parameter settings for different materials can greatly be simplified.

[Yan et al. (2004)] studied WEDM's closed-loop wire tension control system for improving the machining accuracy. They derived the various models of the wire feed control apparatus and wire tension control apparatus were derived to analyze and design the control system. To investigate the performance of the closed-loop wire tension control system they used one-step-ahead adaptive controller and PI controller. They used the dynamic absorbers (shown in figure 5) with the idle rollers of wire transportation mechanism to reduce the vibration of wire tension during wire feeding. They found that, the developed closed loop system can achieve the reasonable performance of transient response and acceptable steady-state error of 7%. Their experimental set-up of the developed closed–loop wire tension control system is shown in figure 4. Their experimental results showed that, the washout of cliff edge measured along the thickness of workpiece and the geometrical contour error of corner cutting can be reduced by 40% and 50%, respectively with the developed system.

[Puri et al. (2003)] studied the wire lag phenomenon in Wire-cut Electrical Discharge Machining (WEDM) and the trend of the variation of the geometrical inaccuracies caused due to wire lag with various machine control parameters. It is very difficult to select the best parametric combination for a particular situations arising out of customer requirements because many factors govern WEDM. Their main objective of the study was to carry out an experimental investigation based on the Taguchi method involving 13 control factors with 3 levels for an orthogonal array L_{27} (3^{13}). To establish the trends of variation of a few important machining criteria with various control parameters they studied all the control factors simultaneously. They concluded that, the pulse on time, pulse off time and pulse peak current during rough cutting, affect the average cutting speed (V_c) the most. They also concluded that, for the highest productivity with the best surface finish and least geometrical inaccuracy cannot be produced by a single set of parametric combination due to wire lag.

Owing to the many regulating machining variables, the optimization of the WEDM process has often proved to be a difficult task. The WEDM process has always been influenced in a complex way with the change in single parameters [Scott et al. (1991)]. Nevertheless, it is very perplexed to relate the output performance measures with the input parameters and to derive an optimal result using an algorithm. Moreover, an effective way of solving the perplex problem of relating the performance measures to the process parameters is the modelling of the process. As modelling provides the verification of the process yielding and an accurate dimensional inspection with higher productivity and better stability for the WEDM process. Nevertheless, the random and complex nature of the erosion process in WEDM requires the application of stochastic as well as deterministic techniques [Williams (1991)]. Consequently, the optimization has always remained a key research area of the WEDM process that, will match the legion the performance measures with process parameters.

[Scott et al. (1991)] developed the empirical models to predict the MRR and SR while machining D2 tool steel. They observed that there was no single combination of levels of the different parameters which, could be optimal under all situations. The non-dominated point approach was applied to locate the optimal machining parameters, using the dynamic programming method. [Miller et al. (2004)] investigated the effects of spark cycle and pulse on-time on wire EDM of metal foams, carbon–carbon bipolar plate and metal bond grinding wheels. [Mahapatra et al. (2006)] attempted to determine the important machining parameters for performance measures in the WEDM process, like MRR, kerf and SF separately.

III. SUMMARY

Experiments performed by many researchers revealed that, the TWR, and SR of WEDM can be reduced by increasing the MRR and by designing WEDM [Yan et al. (2004)]. The pulse on time (T_{on}), pulse off time (T_{off}) and pulse peak current during rough cutting, affect the average cutting speed (V_c) of the wire the most. For the highest productivity with the best surface finish and least geometrical inaccuracy cannot be produced by a single set of parametric combination due to wire lag [Puri et al. (2003)]. Minimization of inaccuracy and in precision due to wire-tool vibration will find potential industrial applications for manufacturing jobs with high-precision contours. The implementation of artificial intelligence based systems in metal cutting process is possible. The latest optimization techniques like Taguchi technique, genetic algorithm, Fuzzy logic and response surface methodology are being applied successfully in industrial applications for optimal selection of process variables for WEDM.

IV. FIGURES AND TABLES

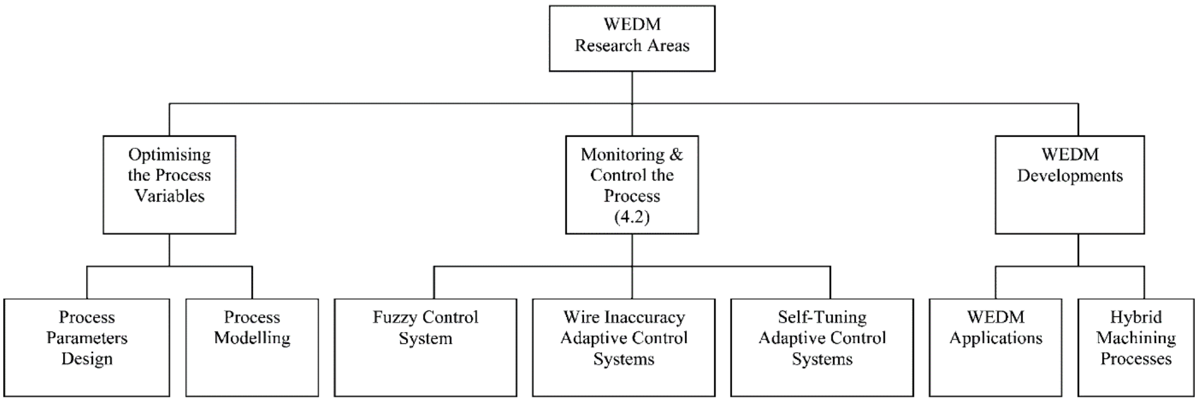

Figure 1: Classification of major WEDM research areas [Ho et al. (2004)].

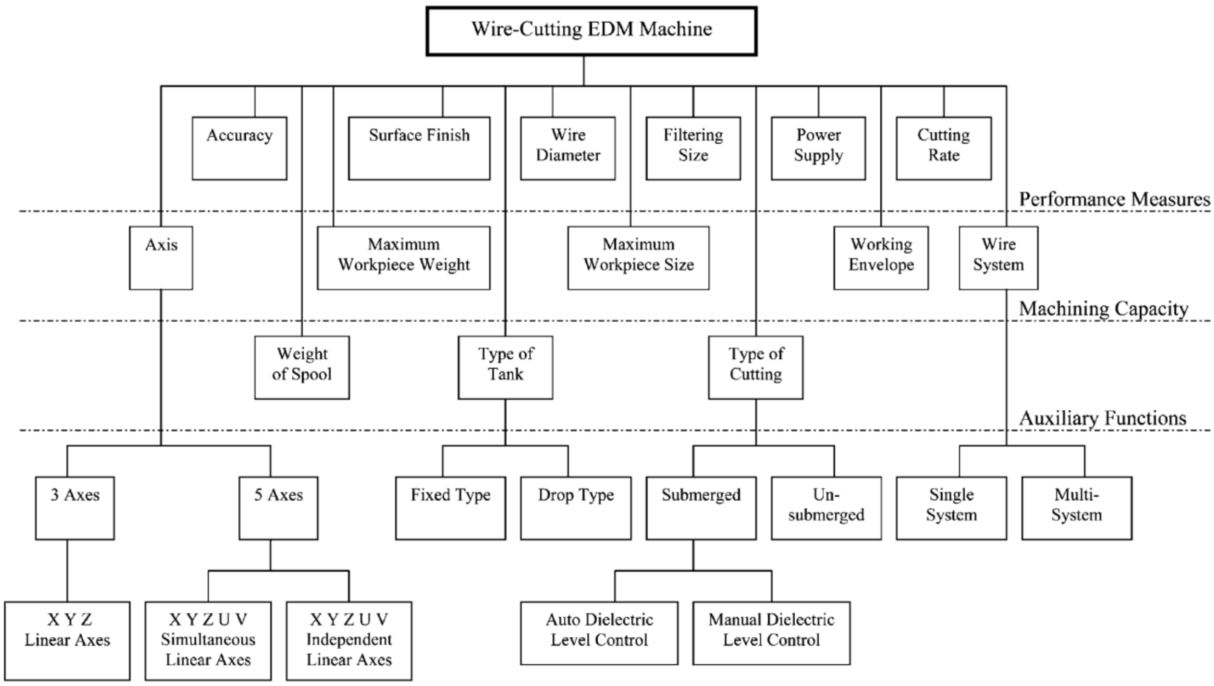

Figure 2: Classification of wire-cutting EDM machine [Ho et al. (2004)].

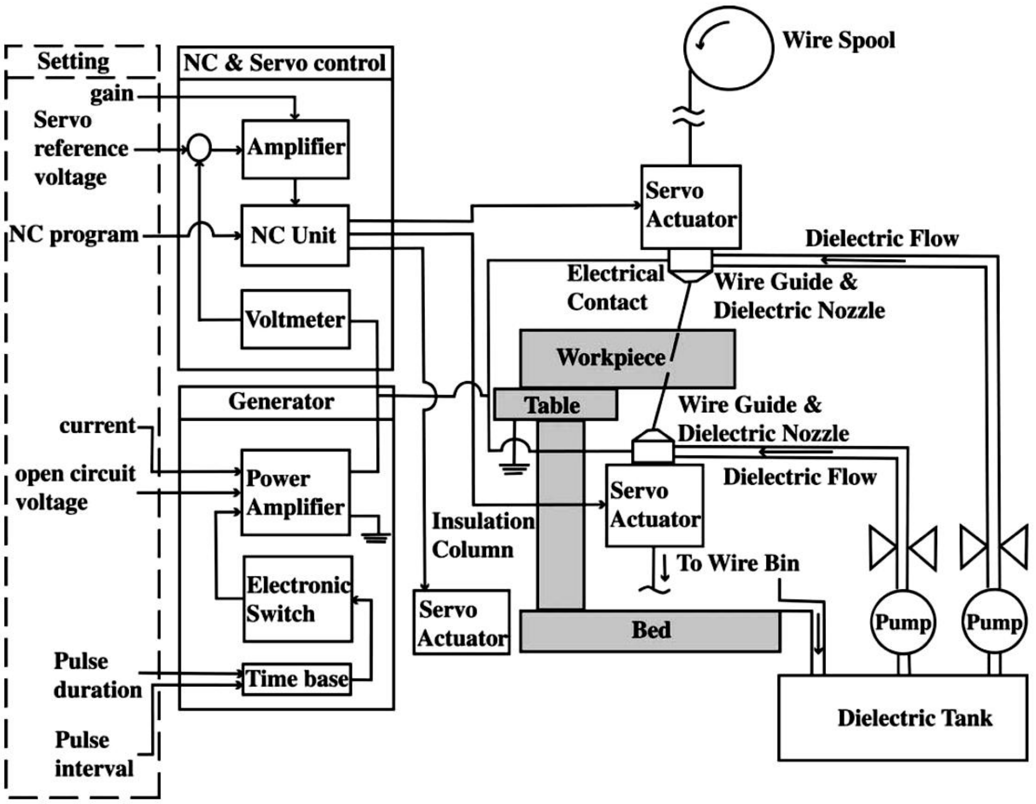

Figure 3: A functional diagram of a wire EDM system [J. Wang et al. (2003)]

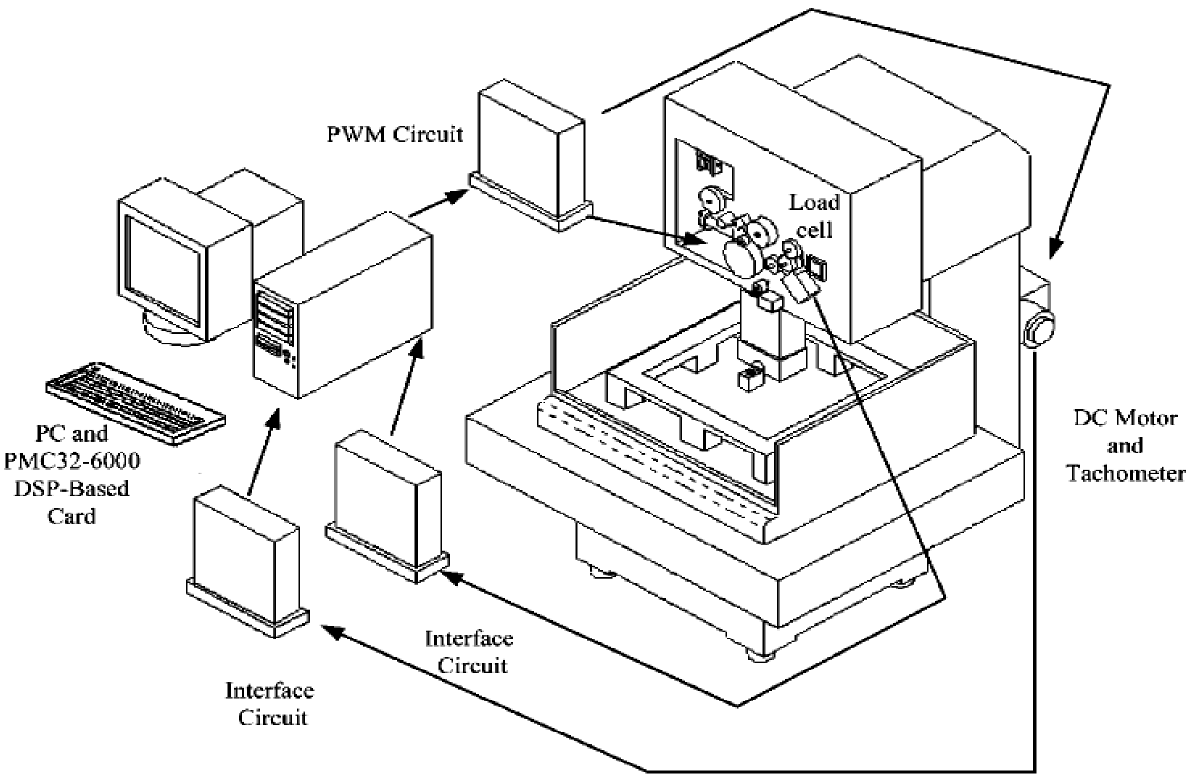

Figure 4: Experimental set-up of the developed closed–loop wire tension control system [Yan et al. (2004)]

Table 1: Variation of machining characteristics varied with respect to significant machining parameters

	Abnormal ratio	Groove width	Machining speed	Surface roughness	Spark frequency	Discharge efficiency
H	↑	↑	↓			
T_{on}	↑	↑	↑	↑		↓
T_{off}			↓		↓	
A_{on}		↑				
A_{off}	↓				↓	
S_v	↓	↑	↓		↓	↓

↑, machining characteristics increasing; ↑ machining characteristics decreasing.

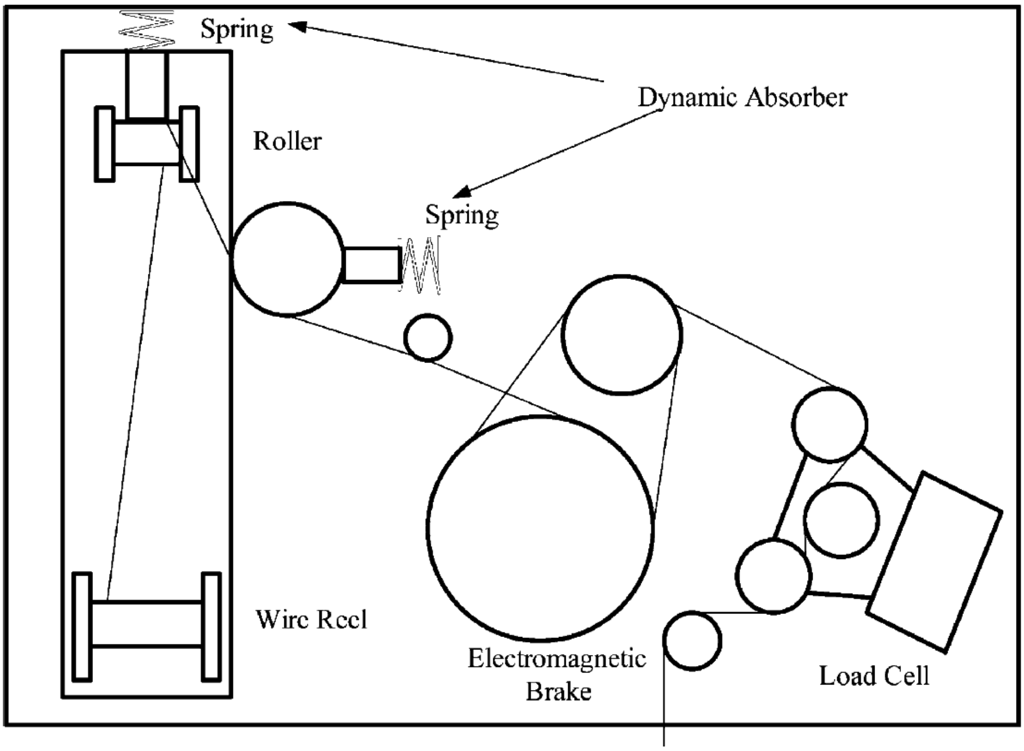

Figure 5: Schematic diagram of wire transportation mechanism with dynamic absorbers [Yan et al. (2004)]

V. Conclusion And Future Scope

The future work might require establishment of the proposed methodology [Lodhi et al. (2014)] for selected machining processes and comparing the results with the experiments. It may also require use of other process parameter models available in the literature [Bhangoria et al. (2010)]. From the above review one can optimize the WEDM process parameters like T_{on}, T_{off}, Current, work piece material and even material of Electrode Wire etc. using Taguchi method for maximizing the MRR and minimizing the surface roughness and TWR by experimental setup. Taguchi technique will help to finalize the number of levels with orthogonal array and thus finalizing the number of experiments. Also the signal to noise ratio will help to observe the behavior of quality characteristics of work piece.

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