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# Response of Wire Electrical Discharge Machining For H13 Using Taguchi L9 Array

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**Abstract**
This paper presents, the experimental study has been made to optimize the process parameters during machining of H-13 by wire electrical discharge machining (WEDM) using Taguchi L9 orthogonal array method. Following input process parameters of WEDM [Pulse-On time (TON), Pulse-Off time (TOFF) and Wire Speed rate (WS) and Wire Tension (WT)] were chosen as variables to study the process output in terms of Material Removal Rate (MRR), Wire wear ratio(WWR),Surface Flatness(SF). In the present work, the parametric optimization method using Taguchi's robust design is proposed for wire-cut electric discharge machining of H-13. H13 has its wide application in pressure die casting tools, extrusion tools, forging dies, hot shear blades, stamping dies, plastic molds. ESR H13 is great for aluminum die-casting tools and plastic mold tools requiring a very high polish. In the present study, the zinc coated copper wire electrode is used as the best compromise of above complex needs. Experimentation has been done by using Taguchi's L9 orthogonal array. Each experiment was conducted under different conditions of pulse on time, pulse off time, wire speed, and wire tension. Result of response of material removal rate, wire wear ratio, surface flatness is considered for improving the machining efficiency. Optimal combinations of parameters were obtained by Taguchi's L9 orthogonal array and Mean of Mean approach method.
**Keywords:**-WEDM, MRR, WWR, SF, Mean of Mean, Taguchi L9 OA, Zinc coated wire**.**

## I. Introduction

EDM was being used at that time to remove broken taps and drills. The early "Tap-Busters" disintegrated taps with hand fed electrodes, burning a hole in the center of the tap or drill, leaving the remaining fragments that could be picked out to saved work pieces as well as expensive parts from being scrapped [1].

It was introduced in the late 1960s', and has revolutionized the tool and die, mold, and metal working industries. It is probably the most exciting and diversified machine tool developed for this industry in the last fifty years, and has numerous advantages [23].

It can machine anything that is electrically conductive regardless of the hardness, from relatively common materials such as tool steel, aluminum, copper, and graphite, to exotic space-age alloys including hastaloy, waspaloy, inconel, titanium, carbide, polycrystalline diamond compacts and conductive ceramics. The wire does not touch the work piece, so there is no physical pressure imparted on the work piece compared to grinding wheels and milling cutters. The amount of clamping pressure required to hold small, thin and fragile parts is minimal, preventing damage or distortion to the work piece [1, 4, and 18].

The researchers have worked on above short comings and used various techniques like layered structure, coating, super quenching, electroplating, galvanizing etc for the performance improvement [21]. But every treatment has its own limitations; some studies have proved that high processing speed requires strong mechanical strength and good electric conductivity of wire electrodes. However, it is found that metallic materials having a high mechanical strength generally shows a low electrical conductivity and vice versa. Hence it is very hard to obtain all the characteristics like high processing speed, improved accuracy of the work piece with a good surface condition. Finally to get best machining conditions, wire electrode must have a good electrical conductance, so that high machining current can flow thorough the electrode. In the present study, the zinc coated copper wire electrode is used as the best compromise of above complex needs [9, 20]. Wire diameter should also be considered when cutting speed is critical [10]. Since smaller diameter wires cannot carry as much current, use the largest diameter wire possible for maximum speed.

## II. LITERATURE REVIEW

Literature survey reveals that the most affecting parameters in the output characteristics of the WEDM are pulse on time, pulse off time, wire speed and wire tension [14]. Researchers had used various optimization techniques for the optimization of WEDM [6, 12, and 13]. But to the best of my knowledge, one single setting for different input parameters of Sodick A320D model of WEDM for a given output parameter has not been achieved.

The present work highlights the inter relationship of input parameters (pulse on time, pulse off time, wire speed and wire tension) to the performance parameters (material removal rate, wire wear ratio and surface flatness, dimensional deviation). In this experimental work an attempt has been made to optimize the multiple performance characteristics of the WEDM on and finally a single setting of the input parameters has been suggested.

Literature survey also shows that very partial work has been done for the optimal use of the characteristics of wire electrode [10, 11]. The most common electrodes used in WEDM are copper, brass, molybdenum and tungsten [2, 8, and 11]. However, for obtaining good work surface finish and high material removal rate the selection of good wire electrode is essential. Copper wire has comparatively low mechanical strength and low working speed. Brass wires have poor workability and surface finish. The disadvantage of the molybdenum wire electrodes lies in its poor discharge capability. Tungsten wire electrodes are relatively costly.

## III. EXPERIMENT WORK

Many parameters in WEDM like polarity, servo control voltage, short pulse time, ignition pulse current, injection pressure, electric temperature, pulse width, pulse duration, wire tension and wire feed speed which can be changed during the machining process [4, 18]. But for the optimization of WEDM a suitable range has to be selected for experiment. The selection of these parameters and experiment design is considered to be a very useful the optimization tasks. It establishes the methods for drawing inferences from observations when these are not exact but subject to variation. In this work, the design of study is done by using Taguchi Method which is explained in Appendix-A. In the this experimental work the performance of the WEDM Sodick A320D model has been studied by considering the various performance measures (material removal rate, wire wear rate, surface flatness) by taking different input parameters (pulse on time, pulse off time, wire tension and Wire feed). After literature review the range of input parameters has been decided, which is given in the Tables 4.2 and 4.3. Three levels of each factor have been selected and L9 orthogonal array has been prepared as suggested by Taguchi, which is given in Table 4.3. The response values obtained for performance measures from orthogonal array are plotted with reference to the mean values and finally optimum conditions were found [14, 20].

**Material removal rate (MRR)**

Material removal rate is the duration in which material is removed from the work piece in a given span of time. Mathematically, it can be given by
MRR = Cs x L $mm^2$/min.

**Wire wear ratio (WWR)**

Wire wear ratio is the ratio of weight loss of wire during machining to the initial wire weight. It can be expressed as
WWR = WWL / IWW

Where WWL is the loss of wire weight and IWW is the initial wire weight.

**Table 1: Input parameters range**

| **Sr.No.** | **Machine Parameter** | **Decided Range** | **Symbol** | **Levels** | | |
|---|---|---|---|---|---|---|
| | | | | **1** | **2** | **3** |
| **1** | **Pulse On Time** | 5-15 | A | 5 | 10 | 15 |
| **2** | **Pulse Off Time** | 15-120 | B | 15 | 60 | 90 |
| **3** | **Wire Speed** | 3-9 | C | 2 | 4 | 6 |
| **4** | **Wire Tension** | 3-9 | D | 4 | 6 | 8 |

## IV. RESULT AND DISCUSSION

**Table 2: Mean response of material removal rate at different level of Ton, Toff, WS and WT.**

| **Trials Levels** | **Mean MRR For TON** | **Mean MRR For TOFF** | **Mean MRR For WS** | **Mean MRR For WT** |
|---|---|---|---|---|
| **1** | **25.19** | **32.39** | **35.37** | **35.75** |
| **2** | **37.09** | **36.41** | **32.69** | **33.59** |
| **3** | **42.75** | **36.24** | **36.97** | **35.68** |

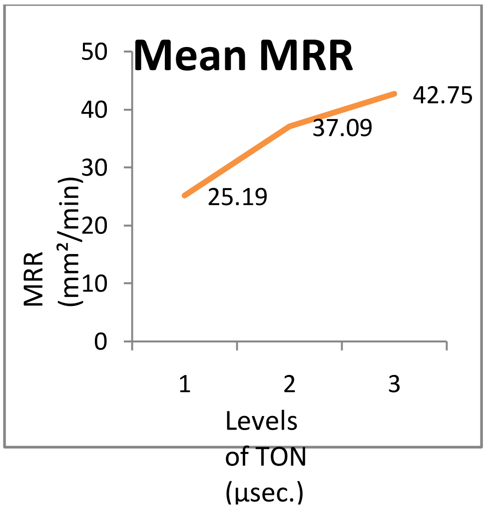
**Table 3: Mean response of wire wear ratio at different level of Ton, Toff, WS and WT.**

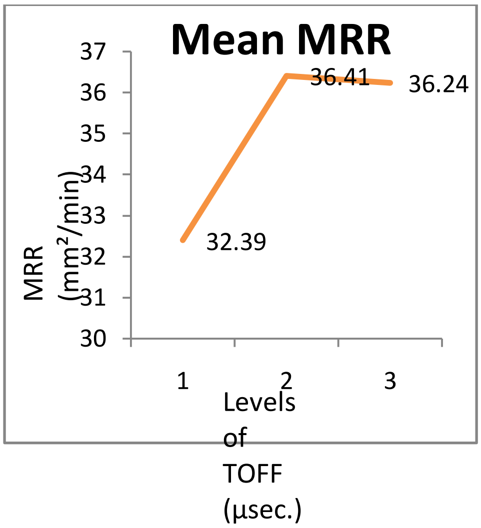
| **Trials Levels** | **Mean WWR For TON** | **Mean WWR For TOFF** | **Mean WWR For WS** | **Mean WWR For WT** |
|---|---|---|---|---|
| **1** | 0.059 | 0.056 | 0.049 | 0.061 |
| **2** | 0.052 | 0.062 | 0.071 | 0.051 |
| **3** | 0.061 | 0.053 | 0.052 | 0.060 |

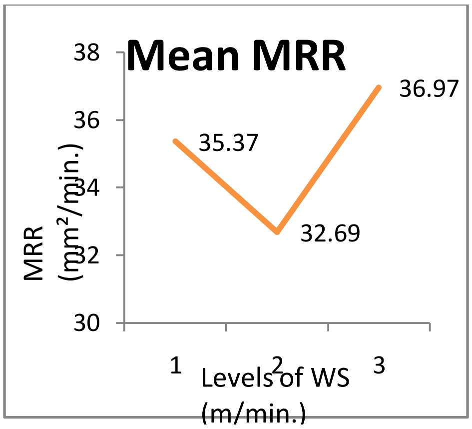
**Table 4: Mean response of surface flatness at different level of Ton, Toff, WS and WT.**

| **Trials Levels** | **Mean SF For TON** | **Mean SF For TOFF** | **Mean SF For WS** | **Mean SF For WT** |
|---|---|---|---|---|
| **1** | 56.66 | 48.88 | 38.88 | 48.88 |
| **2** | 43.33 | 41.11 | 54.44 | 54.44 |
| **3** | 53.33 | 63.33 | 59.99 | 49.99 |

**Figure 1: Graph of Mean response of material removal rate at different level of Ton, Toff, WS and WT.**



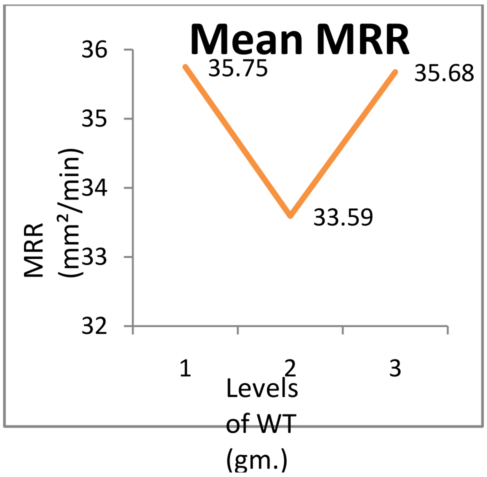
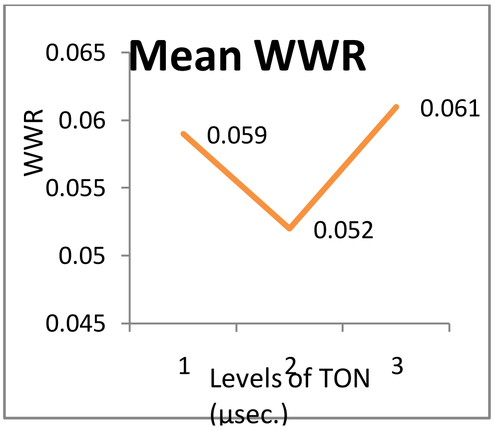
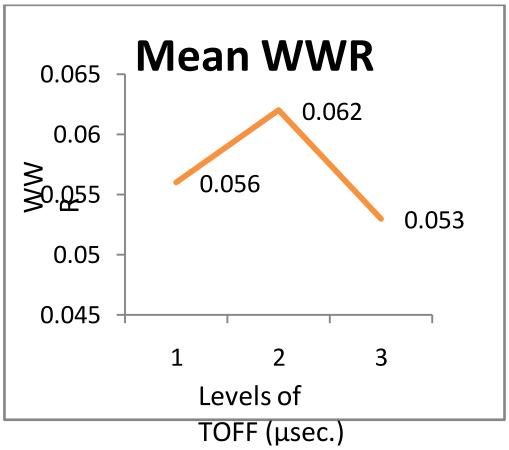
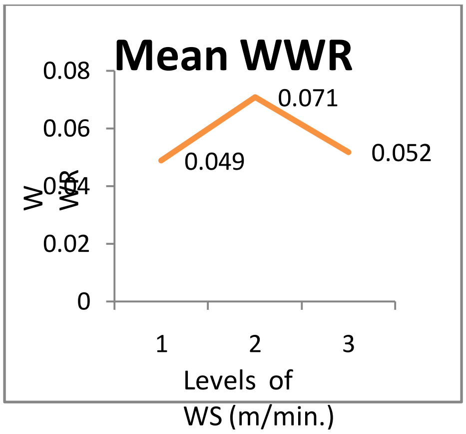




**Figure 2: Graph of Mean response of wire wear ratio at different level of Ton, Toff, WS and WT.**





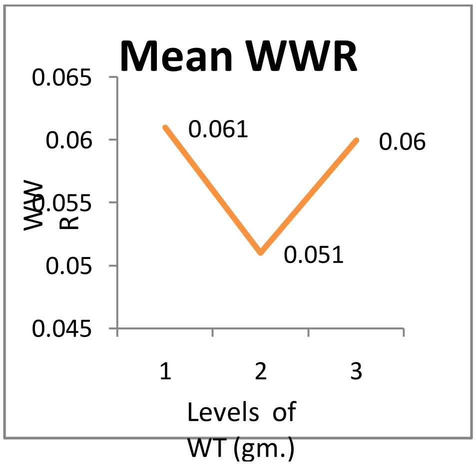
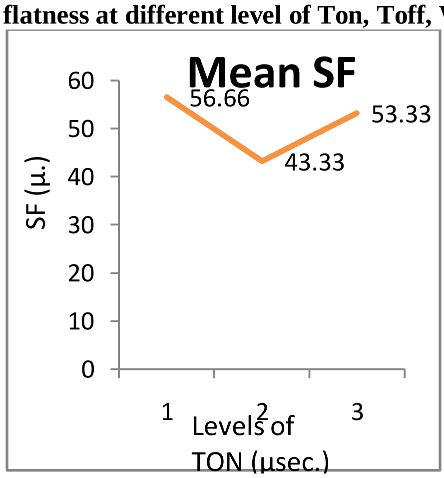
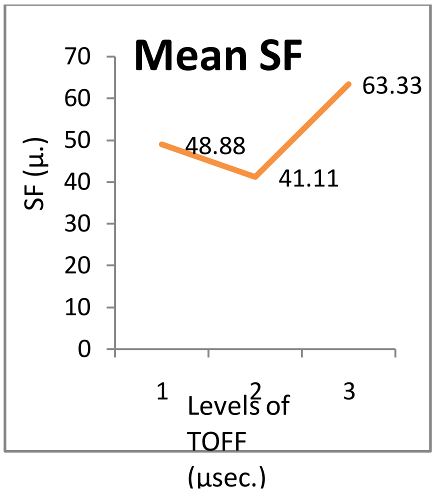
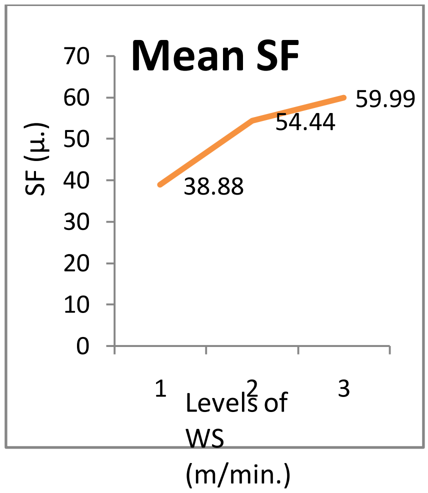
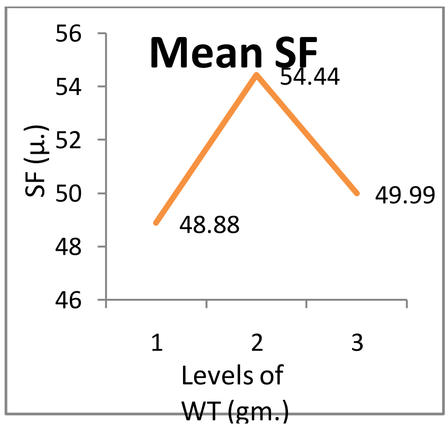




**Figure 3: Graph of Mean response of surface flatness at different level of Ton, Toff, WS and WT.**




## V. CONCLUSION

Several experimental trials on WEDM has been done successfully by applying, Taguchi and Mean of the Mean approach methods. The strategic analysis on selected input parameters pulse on time, wire tension, pulse off time and wire speed feed on multiple performance characteristics such as material removal rate, surface flatness and wire wear ratio for the Sodick A320D WEDM processes has been studied. The Taguchi and Mean of the Mean approach methods offers a strategy for finding optimal, stable results based on a predefined set of analyzed parameter combinations. Design of experiment is expected to gain more accurate answers on system behavior and interaction effects, especially when created on basis of fractional factorial designs. In this work an approach is proposed for selecting the most preferred set of parameters for optimal operation of WEDM. The selection criteria for parameters are based on physical measured outputs of machining i.e. MRR, WWR, and Surface Flatness. All above study reveals that the optimal grouping of the various machining parameters which are given below

1. Material Removal Rate is 3-2-3-1 for most favorable conditions of input parameters. This combination corresponds to pulse on time 15µsec, pulse off time 60µsec, wire speed 6m/min and wire tension 4g.
2. Wire Wear Ratio is 3-2-2-1 for most favorable conditions of input parameters. This combination corresponds to pulse on time 15µsec, pulse off time 60µsec, wire speed 4m/min and wire tension 4g.
3. Surface Flatness is 2-2-1-1 is suitable for most favorable conditions of input parameters. This combination corresponds to pulse on time 10µsec, pulse off time 60µsec, wire speed 2m/min and wire tension 4g.
4. It was observed during experimentation that the pulse on time and pulse off time influence the wire breakage more than any other parameters considered in this study.

## VI. Scope for future work

In the present work, few set-up variables with in a limited range of values were considered which were combined by using Taguchi design of experiment. There is scope for considering more set up variables for complete optimization of WEDM. The levels of each setup variables can be increased further for better working range of machine. Further research might attempt to consider the other performance criteria, such as form accuracy and surface flatness. A typical L9 orthogonal array was used for the design of experiments. More improved results can be obtained by using other orthogonal arrays like L16, L27 etc. The technique presented in this study may also be useful for the other non-traditional machining processes such as electro chemical machining, electron beam machining, laser beam machining, and water jet machining operations for effective utilization of such machine tools.

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