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"INVESTIGATION OF EFFECT OF WEDM PROCESS PARAMETERS ON PERFORMANCE CHARACTERISTICS OF TOOL STEEL GRADE AISI D7"

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Abstract **-**With the increasing demands of high surface finish and machining of complex shape geometries, conventional machining process are now being replaced by non-traditional machining processes. Wire cut EDM is one of the non-traditional processes. Surface roughness & Material removal rate are having crucial importance in the field of machining processes. This report summarizes the Taguchi Optimization Technique, in order to optimize the cutting parameters like Pulse on, Pulse off, Wire feed and sensitivity in wire cut EDM.

The objective of the optimization is to attain maximum material removal rate and the best surface quality simultaneously & separately. In this present study Tool Steel AISI D7 material is used as a workpiece, brass wire of Diameter 0.25 mm is used as a tool and distilled water is used as a Dielectric Fluid. For experimentation Taguchi L9 orthogonal array has been used. The Input parameters selected for optimization are Pulse on Time, Pulse off Time, Wire Feed and Sensitivity. Dielectric Fluid pressure, Wire speed, gap, Voltage, wire tension, resistance & cutting length are taken as fixed parameters.

For each experiment surface roughness has been determined by using contact type Surface comparator and Material removal rate by formula. The optimization values have been obtained for Surface Roughness and Material removal rate by using Taguchi Optimization technique. Optimization value also obtained separately and additionally the Analysis of variance (ANOVA) is too useful to identify the most important factor.

Keywords-WEDM, Taguchi's L9 Orthogonal Array, Surface Roughness, Material Removal rate.

1. INTRODUCTION

In mechanical industry, the demands for alloy materials having high hardness, toughness and impact resistance are increasing. Nevertheless, such materials are difficult to be machined by traditional machining methods. Hence, non-traditional machining methods including electrochemical machining, ultrasonic machining, electrical discharging machine (EDM) etc. are applied to machine such difficult to machine materials. WEDM ispopular in all conventionalEDM process, which used a wire electrode to initialize the sparking process. WEDM process with a thin wire as an electrode transforms electrical energy to thermal energy for cutting materials. With this process, alloy steel, conductive ceramics and aerospace materials can be machined irrespective to their hardness and toughness. Furthermore, WEDM is capable of producing a fine, precise, corrosion and wear resistant surface. A continuously travelling wire electrode made of thin copper, brass or tungsten of diameter 0.05-0.30 mm, which is capable of achieving very small corner radii. There is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining. The WEDM is a well-established machining option for manufacturing geometrically complex or hard material parts that are extremely difficult-to-machine by conventional machining processes. The non-contact machining techniques have been continuously evolving in a mere tool and die making processto a micro-scale application.

2. TAGUCHI METHOD

Taguchi methods are the most recent additions to the toolkit of design, process and manufacturing engineers, and quality assurance experts. In contrast to statistical process control, which attempts to control the factors that adversely affect the quality of production, Taguchi methods focus on design – the development of superior performance designs (of products and manufacturing processes) to deliver quality.

The technique of laying out the conditions of experiments [6] involving multiple factors was first proposed by the Englishman, Sir R.A. Fisher. The method is popularly known as the factorial design of experiments. A full factorial design will identify all possible combinations for a given set of factors. Since most industrial experiments usually involve a significant number of factors, a full factorial design results in a large number of experiments. To reduce the number of experiments to a practical level, only a small set from all the possibilities is selected. The method of selecting a limited number of experiments which produces the most information is known as a partial fraction experiment. Although this method is well known, there are no general guidelines for its application or the analysis of the results obtained by performing the experiments. Taguchi constructed a special set of general design guidelines for factorial experiments that cover many applications.

Taguchi has envisaged a new method of conducting the design of experiments which are based on well-defined guidelines. This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulate the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter. The crux of the orthogonal arrays method lies in choosing the level combinations of the input design variables for each experiment.

3. LITERATURE REVIEW

S.S. Mahapatra and Amar Patnaik in their works observed that, Wire electrical discharge machining (WEDM) is extensively used in machining of conductive materials when precision is of prime importance. Rough cutting operation in WEDM is treated as a challenging one because improvement of more than one machining performance measures viz. metal removal rate (MRR), surface finish (SF) and cutting width (kerf) are sought to obtain precision work. Using Taguchi's parameter design, significant machining parameters affecting the performance measures are identified as discharge current, pulse duration, pulse frequency, wire speed, wire tension, and dielectric flow. It has been observed that a combination of factors for optimization of each performance measure is different. In this study, the relationship between control factors and responses like MRR, SF and kerf are established by means of nonlinear regression analysis, resulting in a valid mathematical model. Finally, genetic algorithm, a popular evolutionary approach, is employed to optimize the wire electrical discharge machining process with multiple objectives. The study demonstrates that the WEDM process parameters can be adjusted to achieve better metal removal rate, surface finish and cutting width simultaneously [1]

In the paper, Jatinder Kapoor, Dr. Sehijpal Singh, Dr. Jaimal Singh Khamba. Says that' Wire electrical discharge machining (WEDM) is an important technology, which demands high-speed cutting and high-precision machining to realize productivity and improved accuracy for manufacturing of press stamping dies, prototype parts etc. Manufacturing advances in Electrical discharge machining (EDM) wires have directly contributed to increased cutting speed and dimensional accuracy.

This paper focuses on evolution of EDM wire from copper to brass and from brass to various coated wire, which has helped make wire EDM machining, the method of choice for high-speed production applications, as well as applications requiring improved contour accuracy and improved surface finishes. Some of the characteristics of high performance wire electrodes have been presented, which significantly increase the wire electrical discharge machining productivity. [2]

In this work, the present work demonstrates optimization of Wire Electrical Discharge Machining process parameters of Incoloy800 super alloy with multiple performance characteristics such as Material Removal Rate (MRR), surface roughness and Kerf based on the Grey–Taguchi Method. The process parameters considered in thisresearch work are Gap Voltage, Pulse On-time, Pulse Off-time and Wire Feed. Taguchi's L27 Orthogonal Array was used to conduct experiments. Optimal levels of process parameters were identified using Grey Relational Analysis and the relatively significant parameters were determined by Analysis of Variance. The variation of output responses with process parameters were mathematically modelled by using non-linear regression analysis method and the models were checked for their adequacy. Result of confirmation experiments shows that the established mathematical models can predict the output responses with reasonable accuracy. [3]

In this paper, Pujari Srinivasa Rao and Koona Ramji made a research and conclude that Wire-cut electric discharge machining of Aluminum-24345 has been considered in the present work. The low rigidity and high material removal rate of aluminum alloys offers a challenging task in obtaining a better surface finish. Experimentation has been done by using Taguchi's L18 (21x37) orthogonal array under different conditions of parameters. The response of surface roughness is considered for improving the machining efficiency. Optimal combinations of parameters were obtained by this method. The confirmation experiment shows, the significant improvement in surface finish (1.03μm) was obtained with this method. Multiple linear regression model have been developed relating the process parameters and machining performance and a high correlation coefficient (r2 = 0.97) indicates the suitability of the proposed model in predicting surface roughness. The study shows that with the minimum number of experiments the stated problem can be solved when compared to full factorial design. Experimental results demonstrate that the machining model is suitable and the Taguchi's method satisfies the practical requirements. [4]

In this paper Y. M. Puri and N. V. Deshpande says that, the paper presents, the use of fuzzy logic in the Taguchi method to optimize Electro Discharge Machining (EDM) process with multiple quality characteristics. Rough machining with EDM gives poor surface finish and has micro cracks and pores. Finish machining gives better surface finish but with very poor machining speed (MRR). Hence achieving higher cutting speed along with better surface finish can be considered as a multi-objective optimization problem. Taguchi method has become a powerful tool in the design of experiments as it improves performance characteristics by optimizing the process parameters and reduces sensitivity of the system performance to noise. However, Taguchi method can optimize single performance characteristics at a time. Hence Taguchi approach is coupled with fuzzy logic for optimization of multiple quality characteristics. Fuzzy reasoning of the multiple performance characteristics has been developed based on fuzzy logic. As a result optimization of complicated multiple performance characteristics is transformed in to the optimization of single response performance index. Electronica EZEECUT-WEDM setup is use as an experimental machine. The work-piece material used is High-Chromium-High-Carbon die steel. Experimental results confirm that this approach is simple, effective and efficient for simultaneous optimization of multiple quality characteristics i.e. MRR and surface finish in EDM. [5]

4. SELECTION OF MATERIAL

AISI D7 is a High-Carbon, High-Chromium Cold Work Steel grade *Tool Steel*. It is composed of (in weight percentage) 2.15-2.50% Carbon (C), 0.60% Manganese (Mn), 0.60% Silicon (Si), 11.50-13.50% Chromium (Cr), 0.30% Nickel (Ni), 0.70-1.20% Molybdenum (Mo), 3.80-4.40% Vanadium (V), 0.25% Copper (Cu), 0.03% Phosphorus (P), 0.03% Sulfur (S), and the base metal Iron (Fe). Other designations of AISI D7 tool steel include UNS T30407 and AISI D7.

Table 4.1 Properties of AISI D7 Material at 25' Deg Temperature:-

Sr. No.	Parameter	Value
01	Ultimate Tensile Strength (Gpa)	190-210
02	Hardness Rockwell C	62.5
03	Density (×1000 kg/m3)	7.72 to 8.0
04	Poisson's Ratio	0.27-0.30

Table 4.2 Chemical Composition % of AISI D7 Material:-

Elements	Weight %
Carbon (C)	2.15-2.50%
Manganese (Mn)	0.60%
Silicon (Si),	0.60%
Chromium (Cr)	11.50-13.50%
Nickel (Ni)	0.30%
Molybdenum (Mo)	0.70-1.20%
Vanadium (V)	3.80-4.40%
Copper (Cu)	0.25%
Phosphorus (P)	0.03%
Sulfur (S)	0.03%
base metal Iron	Remaining

5. EXPERIMENTAL SET-UP

The Wire electric discharge machining (WEDM) of AISI D 7 has been carried out in an 'Ezeecut Plus' Wire Electric Discharge Machine. The parameter settings and machining time were displayed on a screen. The operating and controlling of the WEDM can also be done through the display Screen and a keyboard. Before and after each machining operation, workpiece weights were measured with the help of a Weighing Machine for the purpose of calculating material removal rate (MRR). The thickness of the work pieces were measured by a "Vernier Calliper".

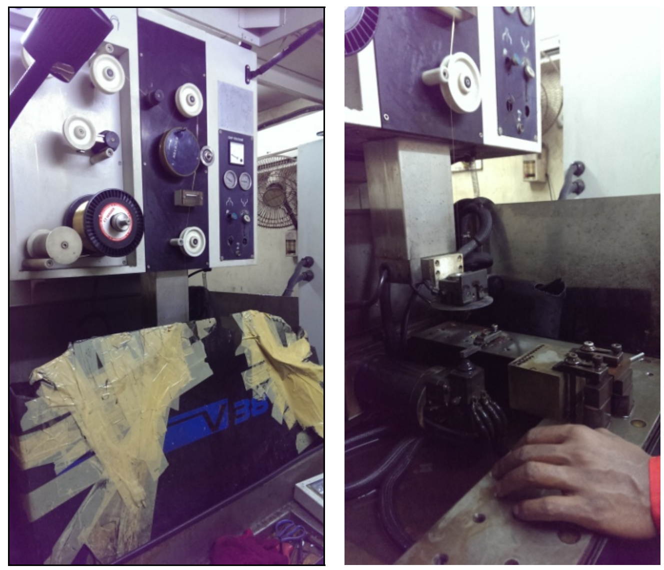


FIG 5.1 - WIRE CUT EDM MACHINE

6. EXPERIMENTAL INVESTIGATION

A. Input Factors

- Pulse on time (Ton),
- Pulse off time (Toff),
- Feed (f),
- Sensitivity (Sen).

B. Responses Measured

- Material Removal Rate (MRR),
- Surface roughness (Ra)

The level values of input factors are shown in Table 6.1

Table 6.1 Level Values of Input Factors

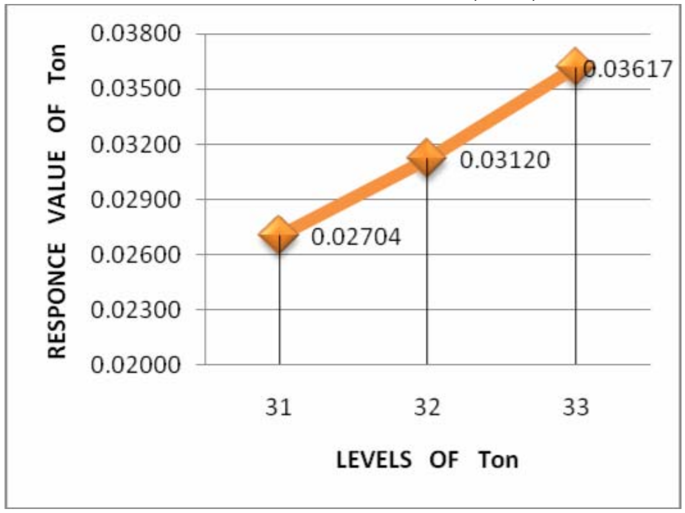
Sr.No.	Factors	Levels		
		1	2	3
1.	Ton	31	32	33
2.	Toff	6	7	8
3.	Feed	80	90	100
4.	Sensitivity	8	9	10

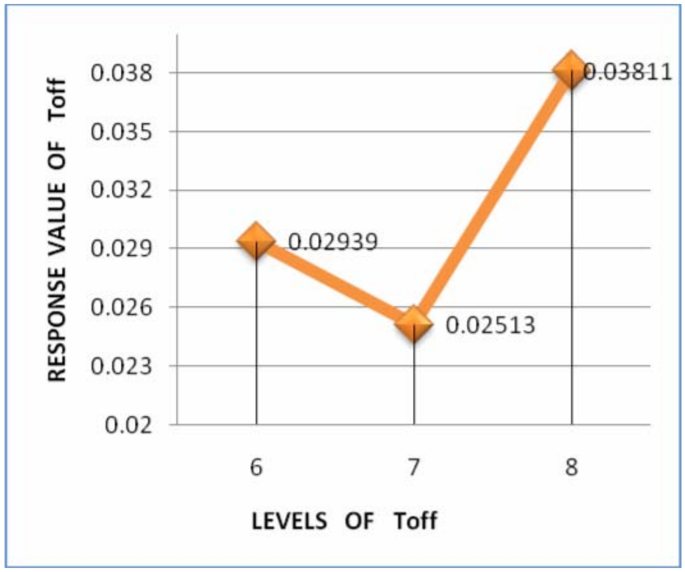
Table 6.2 L9 Design Matrix

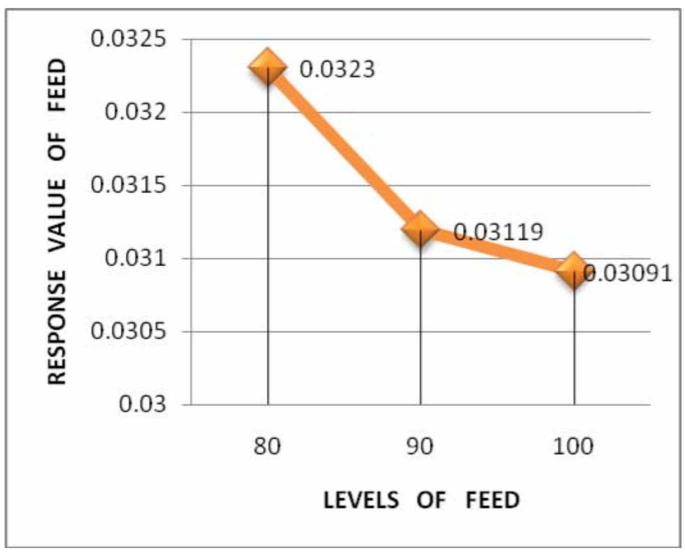
Exp. No.	F 1	F 2	F 3	F 4	MRR (g/min)	Roughness\(Ra)
E1	31	6	80	8	0.020479	2.612
E2	31	7	90	9	0.022748	2.375
E3	31	8	100	10	0.037898	1.44
E4	32	6	90	10	0.031854	1.825
E5	32	7	100	8	0.018992	2.812
E6	32	8	80	9	0.042777	1.205
E7	33	6	100	9	0.035855	1.487
E8	33	7	80	10	0.033666	1.689
E9	33	8	90	8	0.03899	1.265

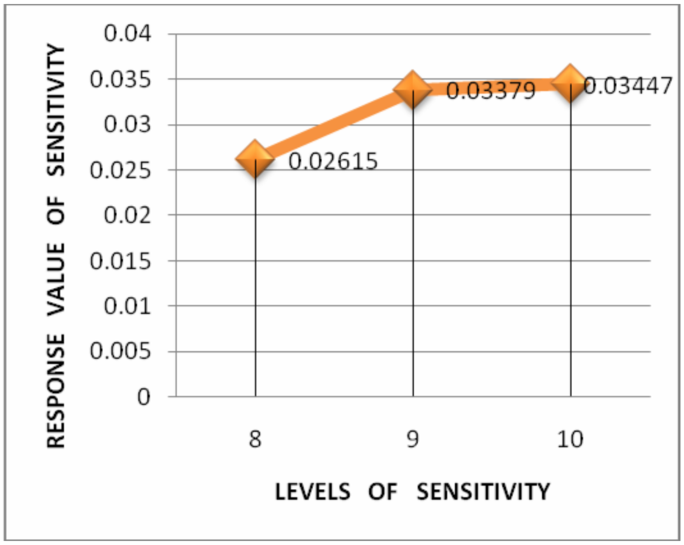
7. RESPONSE GRAPH

A. Effect of Input Factors on Material Removal Rate (MRR)

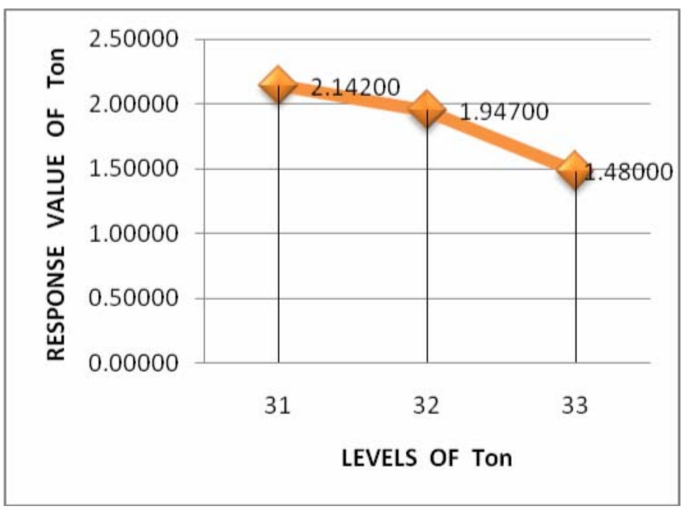


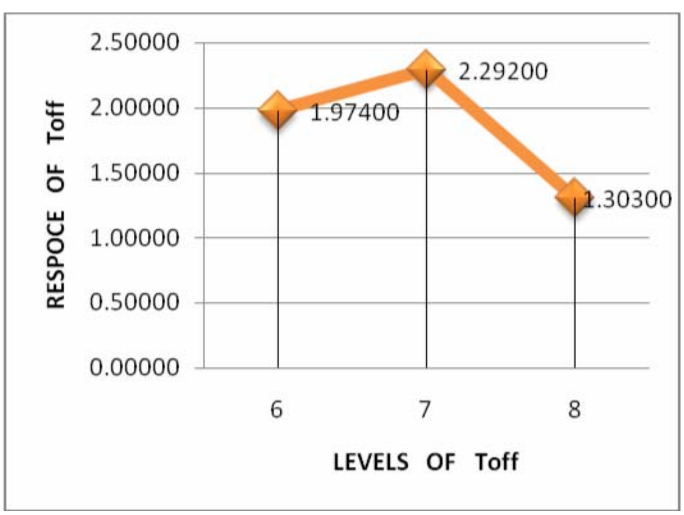


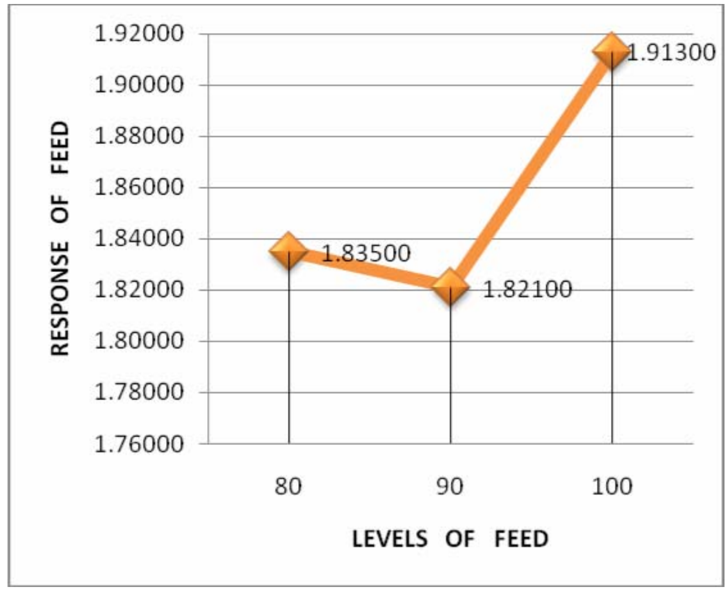




B. EFFECT OF INPUT FACTORS ON SURFACE ROUGHNESS (RA)







8. CONCLUSION

In machining of AISI D7 material by Wire Electric Discharge Machining, the following conclusions may be drawn based on the experimental observations: -

The Material Removal Rate (MRR) mainly affected by Pulse-off time (Toff) and Sensitivity (Sen). The effect of pulse-on time (Ton) is less on MRR. Feed (f) has least effect on it.

The Surface Roughness (Ra) is mainly affected by Sensitivity (Sen) and Pulse-off time (Toff).It is observed that Pulse-on time (Ton), Feed (f) has the least favorable effect on Surface Roughness (Ra).

In Taguchi L9 orthogonal matrix experiment, no interactions between the input factors are considered. But some interaction effect may be present during the experiment. This may result in some observations which do not go with the theoretical belief.

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