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Research Paper

ANALYSIS OF SURFACE ROUGHNESS ON EURONOME 19 BY TAGUCHI'S METHOD, KERF WIDTH

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This study aims to determine the surface roughness of "Euro-Norm". EN-19 medium carbon steel simply called EN 19. This process of measuring surface roughness involves Taguchi's method, Kerf Width processes. The effect of cutting parameters Cutting speed, feed rate, depth of cut, on surface roughness in machining the EN-19 Alloy were investigated. The experiment were conducted by using Taguchi's method while cutting its effect on surface roughness was evaluated and optimum cutting condition for minimizing the surface roughness were determined. In this work, an attempt was made to determine the important machining parameters for performance measure like MRR, SF, and kerf in the WEDM process.

Keywords: "Euro-Norm", EN-19, Surface roughness, Taguchi's method, Kerf width

INTRODUCTION

Nickel based super alloys are finding wide applications in the hot portions of jet turbines such as blades, vanes, and combustion chamber, due to their ability to operate at high temperatures for extended periods of time. The machining of these materials is needed to achieve a near-net shape. As these materials possess high temperature characteristics, they place the cutting tools under tremendous heat, pressure and abrasion, leading to rapid flank wear, crater wear and tool notching at the tool nose, etc., and make them highly difficult to machine, which in turn, affects the dimensional accuracy and surface integrity during machining (Choudhury and EL-Baradie, 1998; and Ezugwu and Okeke, 2002). To resolve the machining difficulty and to ensure the functional characteristics with the desired quality, suitable machining conditions and cutting tools are to be established (Ezugwu, 2005). Apart from the above, it is also necessary to model the process parameters in terms of the functional performance characteristics. Of the functional characteristics, machining induced surface topography is an important one.

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Among the many parameters that characterize surface topography, surface roughness is still one of the most important. It is used to evaluate the surface integrity of the machined components, because it directly controls the surface functions such as friction, wear, lubricant retention and load carrying capacity. It also significantly improves fatigue strength, corrosion resistance, and creep life, which are prerequisites in the case of aerospace components (Ezugwu *et al.*, 2003). Though studies have been carried out on the selection of the cutting conditions and cutting tools with respect to the machining of Inconel material, very few studies have been reported on the machining of the EN 90 alloy. Thus, a detailed machining was contemplated. Researchers in this area attempted to develop models which can predict the surface finish of a material for a variety of machining conditions, such as speed, feed rate, and depth of cut. Reliable models would not only simplify the manufacturing process planning and control, but also assist in optimizing the machinability factors of the materials. Therefore, the purpose of this study is (i) to study the effect of the machining parameters on the quality of the machined surface, (ii) to develop a suitable surface prediction technique, and (iii) to evaluate the prediction ability of the model.

Previous studies on the effect of machining parameters on the Nimonic C-263 alloy indicated that lower cutting speed and higher feed rate were found to cause lower surface finish. It was also reported that the feed rate and depth of cut had a dominant influence on the surface finish and surface damage (Ezilarasan *et al.*, 2001). The choice of the cutting speed, feed rate, depth of cut and tool materials was observed to produce good surface finish and avoid catastrophic tool failure. It was observed that an increase in the cutting speed, feed rate and depth of cut affects the tool life and reduces the surface finish during machining, and the increase in the rake angle and change in approach angles increase the mean shear strength in the shear zone, and also encourage work hardening when machining nickel based alloys (Ezilarasan *et al.*, 2001; and Ezugwu and Okeke, 2002). Inorder to obtain good surface quality and dimensional properties, optimized cutting conditions have to be employed, which also needs a suitable modeling technique for better prediction (Ezilarasan *et al.*, 2001). Work hardening and low thermal conductivity causes heat concentration at the cutting tool chip interface, which causes thermo mechanical stress. This in turn affects tool life, and causes considerable surface damage. Hence, the right choice of cutting condition and tool is very important to increase the surface finish, and tool life, and to reduce the cutting force. Surface roughness plays an important role in many areas and is a factor of great concern in the evaluation of machining accuracy. Several researchers have used Taguchi's method for the design of experiment. Taguchi's method is astatistical tool, adopted experimentally to investigate the influence on surface roughness of the cutting parameters such as cutting speed, feed and depth of cut. It has gained wide popularity in the engineering and scientific communities. Taguchi's method is a powerful tool for the design of high quality systems. It provides a simple, efficient and systematic approach to optimize designs for performance, quality and cost. In the present study, the effect of the cutting parameters on surface roughness during machining of the Nimonic C-263 alloy was studied by utilizing a PVD coated cemented carbide insert. Taguchi's L27 array was used for conducting the experiments, and to optimize the surface finish and cutting conditions. To predict the surface finish the response surface method was adopted.

Mahapatra *et al.* (2006) worked to optimization of Wire Electrical Discharge Machining (WEDM) process parameters using Taguchi method. They used as zinc coated copper wire as the tool material and D2 as the work piece. They used Taguchi method and Genetic algorithms as their technique. They used different parameters like, Discharge current, Pulse duration, Pulse frequency, Wire speed, Wire tension, Dielectric flow rate . They concluded that the Taguchi Experimental design method is used to obtain optimum parameters for optimization of MRR, SF as well as minimization of kerfs width.

Satish Kumar *et al.* (2011) worked to investigation of wire electrical discharge machining characteristics of Al6063/Sicp composite. They are considered Brass wire as the tool material and Al6063 (Aluminium alloy) and Sicp silicon carbide as the work piece material. They used Anova method and DOE as their technique. They used different parameters like pulse on time, pulse off time, gap voltage, wire feed. They concluded that MRR is found to decrease with increase in the percentage volume fractions of Sic particles Metal Matrix Composite (MMC) percentage of Sic increases in the MMC for achieving higher MRR.

Pujari Srinivasa Rao *et al.* (2011) worked Effect of WEDM conditions on surface roughness. A Parametric optimisation using Taguchi method. They used Aluminium BIS (24345) as the work material. They used Taguchi method, Anova and Regression analysis as their Technique. They used different parameters like pulse on time, pulse off time, peak current, flushing pressure of dielectricfliud, wire feed rate setting, wire tension setting, spark gap voltage setting, wire tension setting, spark gap voltage setting, spark gap voltage setting, and servo feed setting. They concluded that Analysis of Variance and S/N ratio determine the importance of parameters and optimum parametric combination respectively for their response of surface roughness. Improved S/ N ratio values and confirmation test result showed the possibility of improvement in surface finish using Taguchi method.

Nihat Tosun (2003) worked The effect of the cutting parameters on performance of WEDM. They used Brass wire as the tool material and AISI140 Steel as the work piece material. He used Anova table as their technique. He used different parameters like pulse duration, open circuit voltage, wire speed, flushing pressure. He concluded that the surface quality of the work piece increases with decreasing pulse duration. The surface roughness increases as the cutting speed increase.

Vishal Parashar *et al.* (2010) worked kerf width analysis for wire cut electro discharge machining of SS304L using design experiments. They used brass wire as the tool material and stainless steel grade 304L as the work piece material. They used Taguchi method and Anova table as their technique. They used parameters like Gap voltage, pulse on time, pulse off time, wire feed, flushing pressure. They concluded that kerf width EDMed work piece depended on gap voltage, pulse on time, and pulse off time, wire feed and flushing pressure. Pulse on time and dielectric flushing pressure is the most significant factors, while gap voltage, pulse off time and wire feed are the less significant factor to the kerf width

Routara *et al.* (2009) worked parametric optimization of CNC wire cut EDM using grey relation relational analysis. They use brass wire as their tool material and AISI A7 High carbon medium chromium die steel as their work material. They used Taguchi method, Anova and Grey relation analysis as their technique. They used different parameters like Gap current, Gap voltage, wire feed rate, Duty factor. They concluded that a gray relational analysis of the experimental results of material removal rate and surface Roughness can convert optimization of single performance characteristic called the grey relation grade. As the result optimization of the complicated multiple performance characteristics can be greatly simplified through this approach.

METHODOLOGY

Wire electrical discharge machining is an advance metal removal process using a thin brass wire as a tool electrode. The work piece and electrode are separated by dielectric medium-deionised water. The travelling of the wire, in a closely controlled manner through the work piece generates spark discharges and then erodes the work piece to produce the desire shape based on the path of tool electrode. The experiments were performed in ELECTRONICA MAXI CUT CNC wire electrical discharge machine. Experiments were carried out by pulse are discharges generated between brass with 0.25 mm in diameter and EN-19 grade of alloy steel. Table 1 shows the chemical composition of the work piece EN-19.

Table 1: Chemical Composition of EN-19 Work Piece

Carbon	0.35-0.45
Manganese	0.50-0.80
Silicon	0.10-0.35
Sulphur	0.40
Phosphorus	0.40
Chromium	0.90-1.40
Molybdenum	0.20-0.40

The process parameters which influence the surface roughness during wire electric discharge machining have been identified as pulse on time, pulse off time, wire tension, and wire feed rate, gap voltage, average gap current and coolant pressure. The operating

Table 2: Wire EDM Operating Conditions

Working Condition Description	Description
Tool	(–) polarity
Work piece	(+) polarity
Wire material	Brass
Gap current (A)	1-15
Pulse on time (s)	1-10
Pulse off time (s)	1-10
Wire diameter (mm)	0.25
Wire tension (g)	0-1800
Wire feed rate (mm/min)	1-15
Gap voltage	40-70
Dielectric fluid	Deionised water

conditions of the machine are shown in the Table 2.

The other factors namely pulse on time, pulse off time, wire tension, wire feed rate, gap voltage and average gap current vary in three range of values, i.e., they are three level factor.

EXPERIMENTAL DESIGN AND SET UP

The experiments are performed as per Taguchi L27 Orthogonal Array. Four machining parameters at 3 levels are taken for conducting experiments.

MRR

MRR is calculated by using the expression mentioned below:

MRR = Kerf width × machine speed × thickness of the material × density of the material

MRR in g/min

Kerf width in mm

Machine speed in mm/min

Thickness in mm and

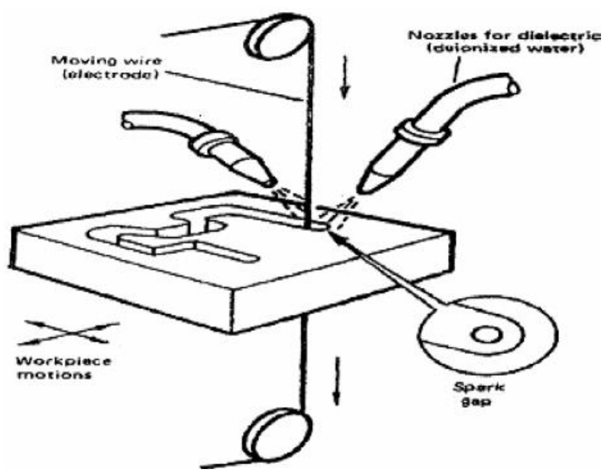
Density in g/mm^3

Surface Roughness

The surface roughness parameters Ra is measured using a roughness tester with cut of length.

The experiments were performed on Electrical Wire Electrical Discharge machine as shown in Figure 1. The basic parts of the Wire Electrical Discharge machine consists of a wire, a worktable, a servo control system, a power supply and dielectric supply system. The Electronic a Wire Electrical Discharge machine allows the operator to choose input parameters according to the material and height of the work piece and tool material from a manual provided by the Wire Electrical Discharge Machining manufacturer

Figure 1: Wire Electrical Discharge Machine



As in typical WEDM the work piece is fixed to a work table, which serves as the electrical ground, inside the EDM machine to complete the circuit. In order to determine orientation of the work piece relative to wire, an edge find command is executed. The wire moves in slowly until it detects the electrical ground of the work piece. The wire is then backed away from the edge about 2.5 mm in order to allow sufficient space for the machine to automatically reheated the wire in the event of wire breakage. This is the starting point from which machining. Finally, the work piece in EDM is submerged in a dielectric fluid for improved flushing and thermal control.

The operation for the metal bond diamond grinding wheels is different from the above set up in the following respects. The grinding wheel is attached to a hub. The wheel/hub assembly is attached to the shaft of a rotary spindle, which is bolted to the work table in the EDM machine. Only the water jets provide the dielectric fluid; the fluid dose not submerges the grinding wheel. Flushing is not an issue, since the wire is only working on the surface, and is not buried within the material. Figure 3 shows micro structure consists of ferrite (light etched) and peartile (dark etched). Etchant used 2% of Nital for 5 seconds. The EN-19 material is check for hardness test in Vickers before heat treatment has been shown in below table.

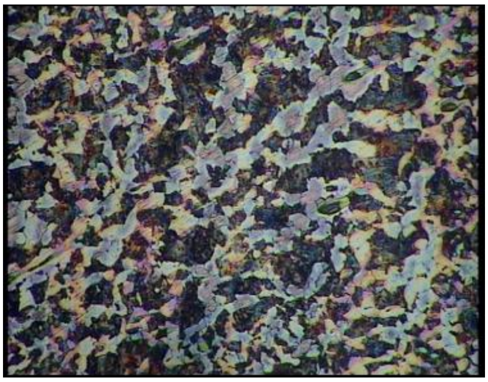
Table 3: The EN-19 Hardness Test

ID No.	Hardness in HV 10	Average in HV 10
EN-19	224,219,216	220

Figure 2: A View of WEDM

Rate of heating : 1000 hr
Soaking temp : 750 °C

Figure 3: Micro Structure of EN-19 Steel Before Hardening

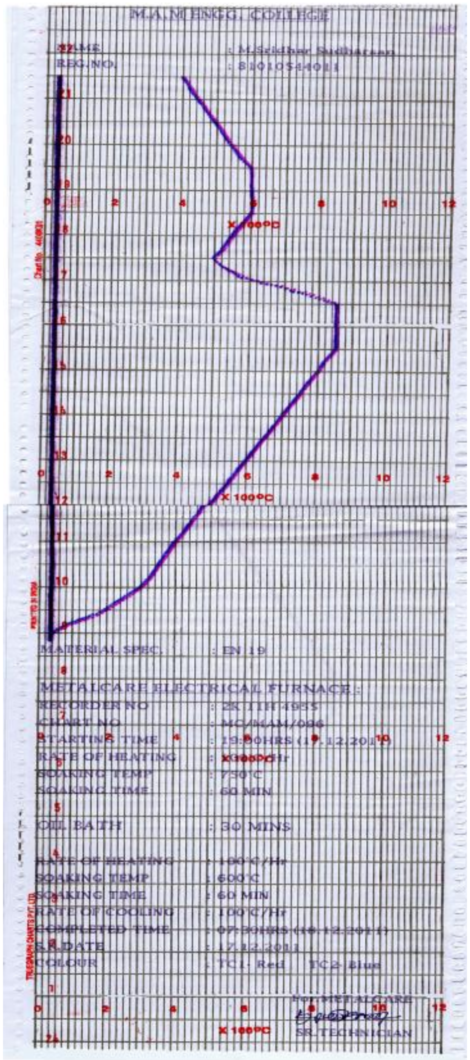


Soaking time : 60 min
Oil bath : 30 min
Rate of heating : 100 °C/Hr

Heat Treatment

The heat treatment is conduct for EN-19 material in an electrical furnace for about 850 °C ± 30 °C. Quenching in oil for 30 min and its tempered @550 °C ± 30 °C.

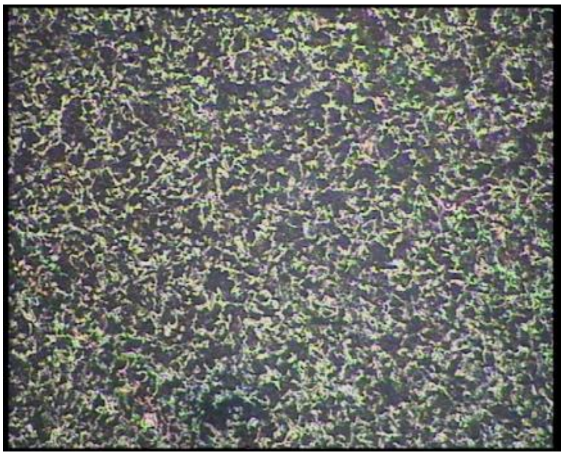
Figure 4: Heat Treatment Chart



Soaking temp : 600 °C
Soaking time : 60 min
Rate of cooling : 100 °C/Hr

The below micro structure shows the structure of fine particles in EN-19 material after the heat treatment is conducted, the micro structure consists of fine grains of ferrite (light etched) and peartile (dark etched) has shown in below figure. Here the etchant used is 2% Nital for 10 seconds.

Figure 5: Micro Structure of EN-19 (After Heat Treatment)



Calculation of MRR

MRR = Kerfwidth × Thickness of the material × Machine speed × Density of the material

For first row we find the MRR

MRR = 0.380 × 30 × 0.7 × 7.89

MRR = 0.051032 gm/min

RESULTS AND DISCUSSION

From the Figure 8, We find that MRR increases on increase of Pulse on Time (T_{on}) only. But were as MRR decreases on increase of Pulse off Time (T_{off}), Wire feed and Voltage. While referring Graph 2 in Figure 7, the K_{erf} width (K_{erf}) increases on increasing the Pulse on Time (T_{on}), Wire feed and Voltage, where as the K_{erf} width (K_{erf}) decreases on increase of pulse off time (T_{off}).

From the Graph 3 in Figure 7, the surface roughness (R_a) increases on increase of Pulse

Figure 6: MRR and Surface Measurement

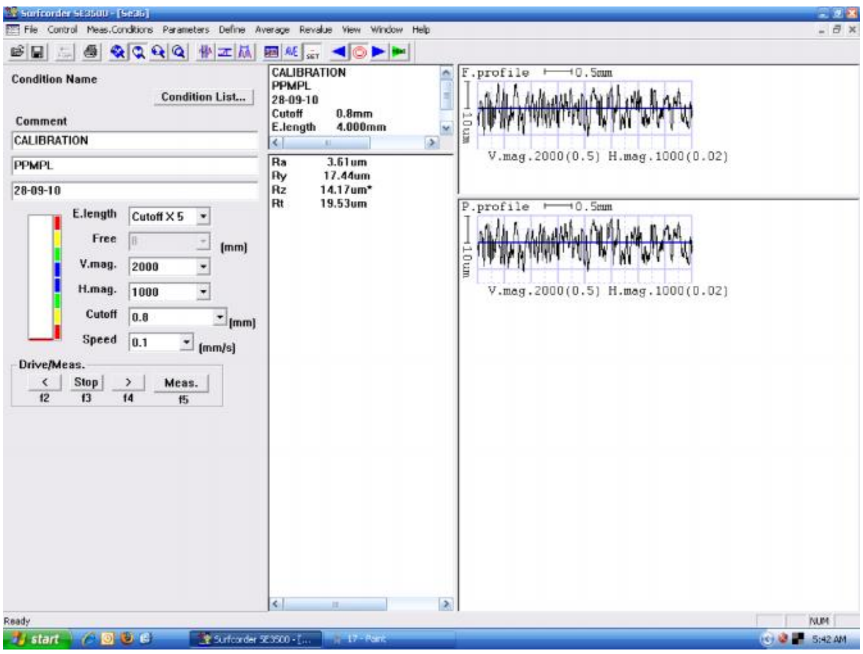


Figure 7: Kerf Width Value

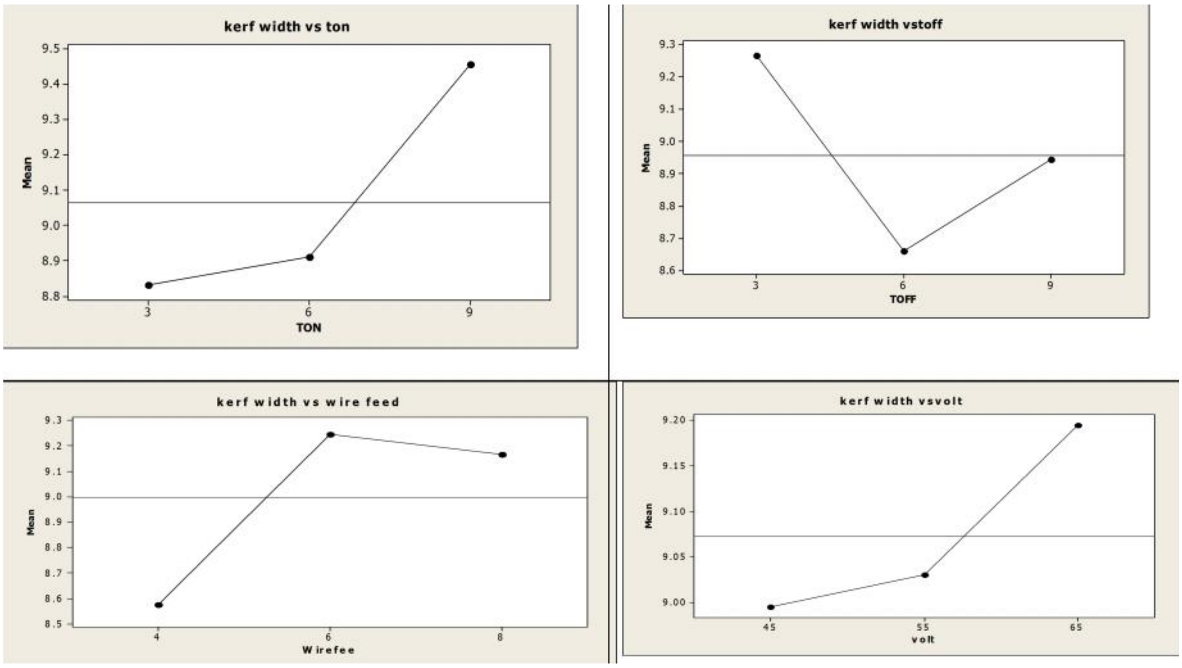
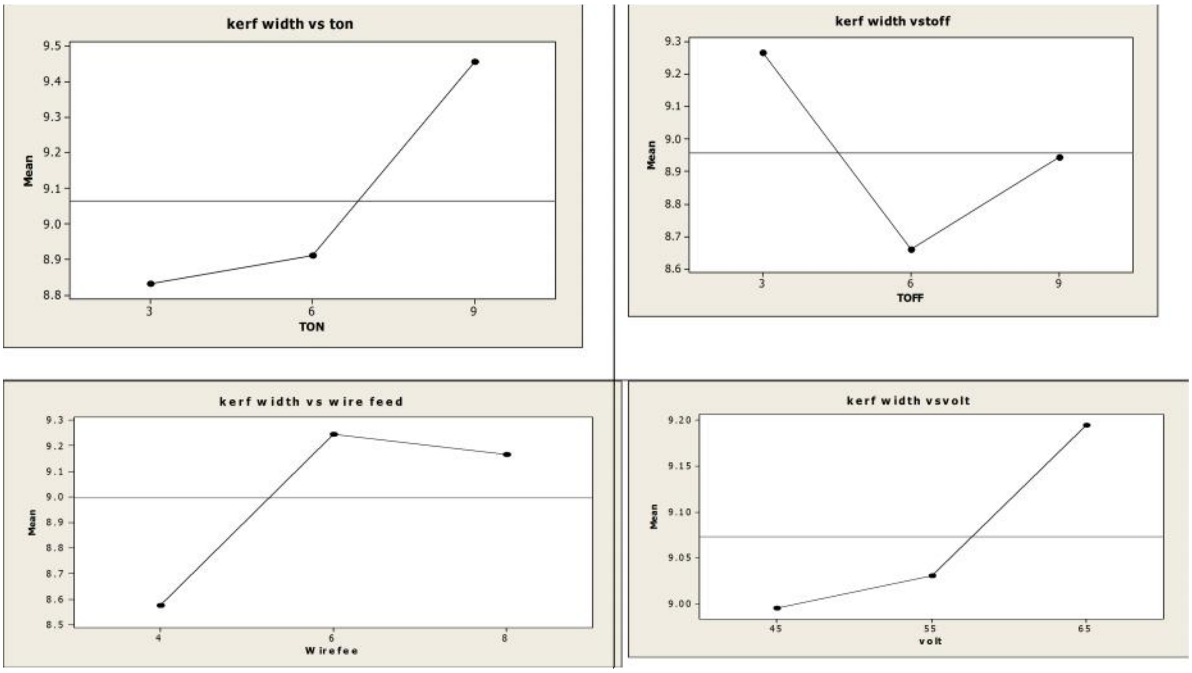


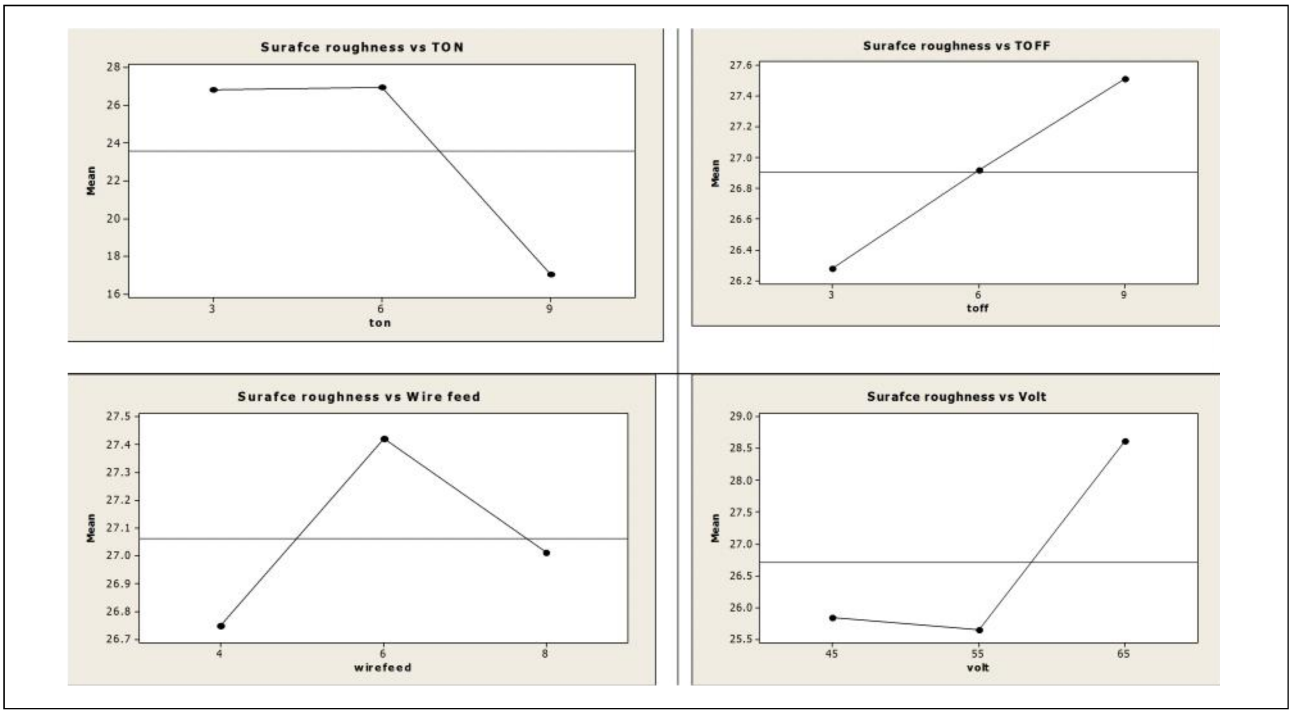
Figure 8: Surface Roughness Graph



off Time (T_{off}), Voltage and Pulse on Time (T_{on}). The Surface Roughness (R_a) decreases on increase of Wire feed

While analyzing the Signal to Noise Ratio (S/N) Graph 4 in Figure 8, the larger the Better values for MRR are found:

Figure 6 (Cont.)



Level 3 (C_1) for pulse on Time (T_{on})

Level 1 (A_2) for Pulse off Time (T_{off})

Level 1 (A_3) for Wire feed and

Level 1 (A_4) Voltage

While referring Figure 8, the Signal to Noise Ratio(S/N) for Kerf Width the lower the Better Values are found

Level 1 (A_1) for pulse on Time (T_{on})

Level 2 (B_2) for Pulse off Time (T_{off})

Level 1 (A_3) for Wire feed

Level 1 (A_4) for Voltage .

From the Graph 6 in Figure 8, the Signal to Noise Ratio (S/N) for Surface Roughness (R_a) the Values noticed the lower the better are:

Level 3 (A_3) for pulse on time (T_{on})

Level 1 (A_2) for pulse off time (T_{off})

Level 1 (A_3) for Wire feed

Level 2 (B_2) for Voltage.

The optimum value noticed for increased MRR – C_1, A_2, A_3, A_4

The optimum value noticed for decreased Kerf Width – A_1, B_2, A_3, A_4

The optimum value noticed for decreased surface Roughness – A_3, A_2, A_3, B_2

The optimum values are experimented and validate.

CONCLUSION

In this work, an attempt was made to determine the important machining parameters for performance measure like MRR, SF, and kerf in the WEDM process.

The following conclusions are drawn from the experimental study of EN-19 alloy steel material machining.

1. Machine speed, pulse off time, wire speed and voltage increase the performance of MRR.

2. Pulse on time affects the performance of MRR.
3. Surface roughness is increased by increasing the Machine speed, gap voltage, pulse duration and reduced due to wire feed.
4. The kerf width performances on increase of pulse off time only and affects due to discharge current, voltage, and wire feed.
5. The optimum search of machining parameter values for the objective of maximizing of MRR and minimization Ra and kerf width are formulated from S/N ratio and the values are (C_1, A_2, A_3, A_4) foe higher better MRR values for kerf width (A_1, B_2, A_3, A_4) and the values for surface roughness are (C_3, A_2, A_3, B_2) respectively.
6. Further non-traditional optimization techniques can be used for optimizing the parameters and comparison with the experimental work and also with other alloy steels.

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