Optimize the process parameters of wire EDM and to analyse the welding characteristics of tig welding joints using AISI 308

Y Kumarswamy[1], *P* Durga Ganesh[1], *K* Ravi Kumar[1], *S* Sai Varun[1], *G* Jagan Vamsi[1], and *Y* Phaneendra[1]*

[1] Mechanical Engineering, Vignan's Institute of Information Technology, Duvvada, Visakhapatnam, Andhra Pradesh, India.

Abstract. Wire Cut EDM technique is widely used to make small and precision cuts. Generally, a material with fragile geometry and hard structure is cut using a wire cut EDM. The main advantage of this method is that, it is a non-conventional machining process therefore it does not have a contact between the tool (wire) and the workpiece. This advantage gives it an edge over other machining techniques and it makes the process capable of machining even the weak structured and delicate materials. In the present experimental work, by using various machining parameters (Pulse on Time, Pulse off Time, and Wire Speed) were optimized using Taguchi's L9 orthogonal array. Welding is most the important industrial processes, therefore lots of techniques have been developed to get an efficient and low-cost welding process for different types of materials. In this we will discuss about the welding characteristics of the of tig welding joints produced using different currents. That is, by changing the voltages for the number of passes to improve and strengthen the welded joint The research work aims to optimize the wire cut EDM process parameters for AISI 308 steel and analyze the welding characteristics of Tungsten Inert Gas (TIG) welded joints of the same material. The study intends to find the optimum combination of process parameters that would lead to the highest material removal rate, lowest wear rate, and best tensile properties of the material.

keywords: AISI Low carbon steel, TIG welding, Wire EDM, Mechanical properties, L9 orthogonal array, Taguchi.

1 Introduction

Steel is vital for a wide range of industrial applications, manufacturing Ammos, building projects, and other uses. As a result, due to its ability to affordably provide a variety of new qualities. Electrical discharge machining, or wire cut EDM, uses a thin wire to cut through a workpiece, usually one made of conductive material including metal, with the assistance of

*Corresponding author:phaneendraviit@gmail.com.

an electrically charged spark that is sent via the wire. The procedure is frequently alluded to as wire erosion or wire EDM. Many industrial processes are used in the application of steel, among which welding is regarded as crucial. The thermochemical reaction that takes place in the fusion zone (weld pools) is thought to be largely responsible for the heat.

The study by, Shivkant Tilekar, Sankhashuvra Das, and P.K. Patowari (2014) examine the impact of process variables on the kerf width and surface roughness of aluminium and mild steel with a single objective. To optimise, one uses the Taguchi method. The input parameters employed in the experiment are the wire feed rate, input current, spark on time, and spark off time [1]. In the study by Sahil Sharma et al. (2020), a 0.25 mm diameter wire electrode was used to machine AISI D2 die steel with a 13 mm diameter. Pulse on time, pulse off time, peak current, and wire tension are employed as the input process parameters to study the effects of these factors on response characteristics such material removal rate The Taguchi L9 orthogonal array was used to investigate the machining time [2]. In a similar vein, the study by Nanchariah Tata, Ravikumar Pacharu, and Sameer Kumar Devarkonda (2021) sought to determine the impact of wire cut EDM (WEDM) process parameters on the machining of alloy INCONEL 625. These parameters were optimised for roughness values (Ra) and material removal rate (MRR). Peak current, pulse time on/off, supply voltage, and polarity are the variables that can alter the characteristics of the machining, cutting, or drilling in the wire cut EDM process. The impact of WEDM settings on the alloy INCONEL 625 is examined in this study. The supply voltage and input process parameters such as pulse on/off duration are chosen, and the quality attributes These include things like surface finish and material removal rate [3]. Similar to this, investigations on stainless steel (AISI 630) workpieces employing WEDM have been conducted utilising the study by Jitender Kumar, Tarun Soota, and S.K. Rajput (2020) in this publication. Results for the response parameters material removal rate, surface roughness, and tool wear rate were obtained through experimentation [4]. Six machining parameters (Pulse on Time, Pulse off Time, Wire Tension, Spark Gap, Gap Voltage, and Wire Speed) were optimised using Taguchi's L27 orthogonal array in the study by Dhruv Batt and Ashish Goyal (2019) in this publication. Material Removal Rate (MRR) and Surface Roughness (SR), the reactions to the tests, were examined using Design of Experiment (DOE) and Grey Relational analysis (GRA) [5]. Bishub Choudhury and M. Chandrasekaran (2017) conducted research on the welding characteristics of aerospace materials. According to the findings of this investigation, the high dynamic shear strength and higher strain hardening propensity make welding problematic. In this field, welding studies of nickel-based superalloys using various welding methods, such as gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), electron beam welding (EBW), laser beam welding (LBW), and friction stir welding (FSW), are being conducted. Most welding procedures have been shown to be suitable for welding nickel-based alloys, with EBW and LBW processes providing advantages such as low heat input, high weld depth-to-width ratio, small HAZ, reduced distortion, and excellent mechanical properties when compared to arc welding of nickel-based alloys. As part of the researchers attempted modelling and process parameter optimisation using experimental welding inquiry in order to achieve improved weld bead geometry [6]. Similar to this, Ahmed Ibrahim Razooqi et al.'s one study from 2019 looked into how DC current affected the mechanical characteristics of TIG welded joints on low carbon steel 1020 AISI. In this study, it was discovered that TIG welding joints made with variable DC current had better tensile strength, elongation, and hardness compared to some of the prepared sheet metals that were shot peened with steel balls with a diameter of 1.25mm for 30 minutes before welding, then to be welded at the same welding conditions. The improvement of the mechanical performance was achieved by utilising this changing DC current the characteristics of those specific welded junctions [7]. The morphology, microstructure, and mechanical properties of the 5803 aluminium alloy were studied for the laser beam oscillating welding features in another work by Shangren Li et al. (2020). In this investigation, we discovered that the weld porosity could be suppressed by laser beam oscillation when the oscillating frequency was over 200 Hz and the oscillating diameter was over 2 mm. The laser beam oscillation could refine grains and promote the uniform distribution of the (Mg2Al3) phase in the weld fusion zone, increasing the micro-hardness of the weld zone, according to the results of a microstructure analysis using an electron probe micro-analyser and electron backscattered diffraction. Tensile test results also showed that the tensile strength and the The elongation of laser oscillating welding joints was significantly greater than that of non-oscillating joints, owing mostly to the elimination of porosity [8]. In contrast, Minguhi pan et al. (2022) studied the welding characteristics, mechanical properties, and penetration depth of T-joints thin-walled pieces of aluminium alloy 6061-T6 for various tig welding currents. The microstructure changes of the weld zone (WZ), heat-affected zone (HAZ), and base metal (BM), as well as the mechanical properties of the T-welded joints, were discovered in this study the results demonstrate that the yield and tensile strength of T-welded joints account for less than 37% and 74% of the base metal (BM) strength, respectively. Furthermore, welding currents have a significant impact on the welding penetration depth and microstructure of T-welded connections. These findings are likely to serve as a platform for further research of the welding process, reduction of welding errors, and promotion of mechanical qualities for thin-walled parts [9]. After evaluating a number of research publications on wire EDM and the mechanical qualities of welding joints using various DC currents, the following conclusion was reached.

2 Methodology

In this work, for optimization of process parameters of the wire cut EDM the various steps have been followed we have used AISI 308 as the material.

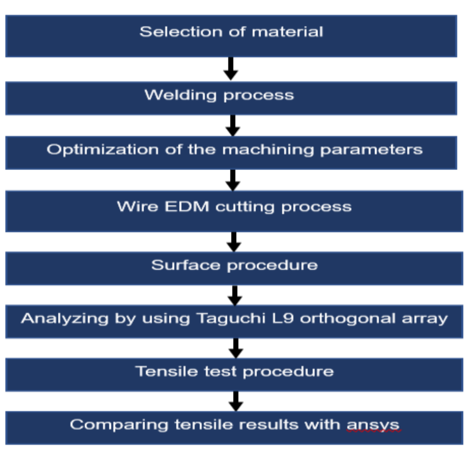

Fig.1. Represents the design, analysis, and fabrication

2.1 Selection of material

The austenitic stainless steel AISI 308 is designed for primary shaping into wrought items. The qualities listed are appropriate for the annealed state. The AISI number for this material is 308. AISI 308 stainless steel is compared to wrought austenitic stainless steels (top), all iron alloys (middle), and the whole database (bottom) in the graph bars on the material properties cards below. A full bar indicates that this is the greatest value in the set. A half-full bar indicates that it is 50% of the highest, and so on.

Table 1. Chemical composition of the AISI 308

Iron	Chromium	Nickel	Manganese	Silicon	Carbon	Phosphorous	Sulphur
71%	21%	12%	2.0%	0.75%	0.080%	0.045%	0.030%

Table 2. Mechanical properties of AISI 308

Material	Density (g/cm³)	Young's Modulus (GPa)	Poisson's Ratio	Tensile Yield Strength (MPa)
AISI 308	8	193	0.27-0.30	585

2.2 Welding process

The TIG welding procedure has been used to prepare the weld junction. The preparation of the welding joint was done using the same type of filler rod (AISI 308). The first plate was chosen, bevelled by 45 degrees on the grinding machine, and then the other two plates were positioned. After that, the welding procedure was initiated. Three passes, or runs, were made to attach the plates, and three different voltages were employed for each run (see Table 3). The first run is referred to as the "ROOT" and has a voltage of 74 volts. The second run is referred to as the "FILLING" and has a voltage of 110 volts.

Table 3. Voltages used for welding

Runs	Root (volts)	Filling (volts)	Tapping (volts)
Voltages	74	110	120

2.3 Wire EDM cutting process

In this step we have been selected the square of 50*50 mm plates shown in fig 2 to cut through this wire EDM and then we made another rectangle cuts at the corner of that square plate the dimensions of that rectangle were the 30*10 mm from the corner and also, we have been made another circular cut on that square plate of diameter 10mm. After that we need to calculate the material removal rate and also the surface roughness of the specimen which has done through the wire EDM machine. We were also taken a standard dimension of the tensile specimen according to the ASTM E8 the tensile specimen had been made through this wire EDM cutting process.

Fig.2. Specimens after cutting with Wire EDM

2.4 surface roughness test

For surface roughness test we had used the talysurf for checking the roughness of the specimen we had got three values i.e., Ra, Rq, & Rz. The talysurf is the device which is used to check the roughness of the material shown in fig 3.

Fig.3. Talysurf device

2.5 Universal testing machine

In this test the tensile specimens have been tested by using the computerized universal testing machine (UTM) the tested specimens had been shown in fig 4 and the following results and graphs have been obtained.

Fig. 4. Tested specimens

3 Results and Discussions

The results obtained during the machining process the material removal rate and the surface roughness had been obtained. The results were shown in table no. 4.

Table 4. Results obtained while testing

Pulse on Time (us)	Pulse off Time (us)	Wire Speed	MRR (gm/min)	Avg. Ra (µm)	weights (gm)	
					weight 1	weight 2
30	7	150	0.015	4.911	98	97.105
30	8	155	0.0203	4.5365	98	96.899
30	9	160	0.0141	4.83	98	97.162
35	7	155	0.0136	4.7945	98	97.097
35	8	160	0.0135	4.3415	98	97.189
35	9	150	0.0158	4.5625	98	97.036
40	7	160	0.0246	5.2865	98	96.745
40	8	150	0.0171	4.6545	98	96.988
40	9	155	0.0164	4.7195	98	97.013

3.1 Taguchi analysis

Taguchi Analysis: surface roughness Ra (Avg_1) versus Pulse on Time (μs), Pulse off Time (μs), Wire Speed (rpm)

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It shows that the roughness of the specimen is better when the pulse on time is 40µs and the pulse off time is 7µs and the wire speed is 160rpm. The roughness obtained by it was the optimum.

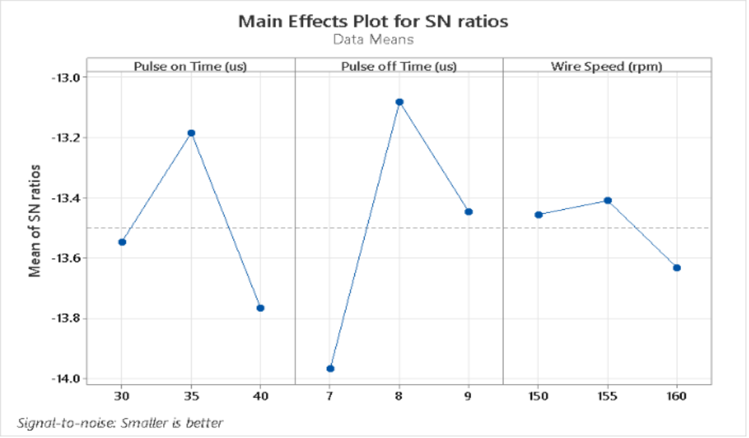

Fig .5. Main effect plots of surface roughness

Table 5. Response Table for Means

Level	**Pulse on Time (µs)**	**Pulse off Time (µs)**	**Wire Speed (rpm)**
1	4.759	4.997	4.709
2	4.566	4.511	4.683
3	4.887	4.704	4.819
Delta	0.321	0.486	0.136
Rank	2	1	3

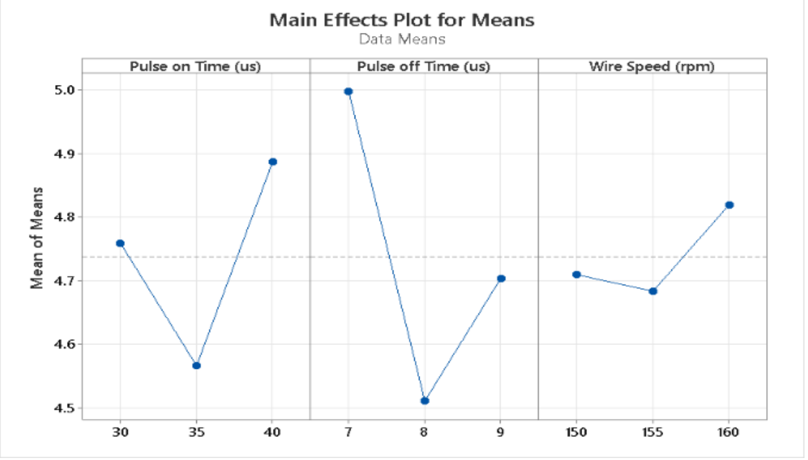

Fig.6. Main effect plots of surface roughness

In this graph it shows that the roughness of the specimen is better when the pulse on time is 35µs and the pulse off time is 7µs and the wire speed is 155rpm. The roughness obtained by it was the optimum.

Taguchi Analysis: MRR_1 (gm/min) versus Pulse on Time (μs), Pulse off Time (μs), Wire Speed (rpm)

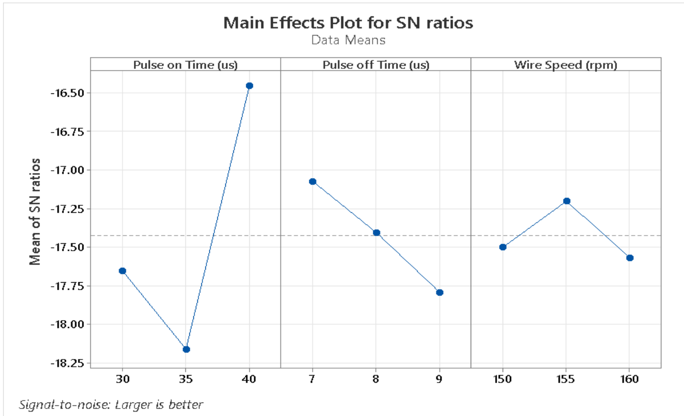

Fig.7. Main effect plots of material removal rate

It shows that the material removal rate of the specimen is better when the pulse on time is 40µs and the pulse off time is 7µs and the wire speed is 155rpm. The roughness obtained by it was the optimum.

Table 6. Response Table for Means

Level	Pulse on Time (μs)	Pulse off Time (μs)	Wire Speed (rpm)
1	0.1319	0.1419	0.1335
2	0.1239	0.1360	0.1385
3	0.1513	0.1293	0.1351
Delta	0.0274	0.0127	0.0050
Rank	1	2	3

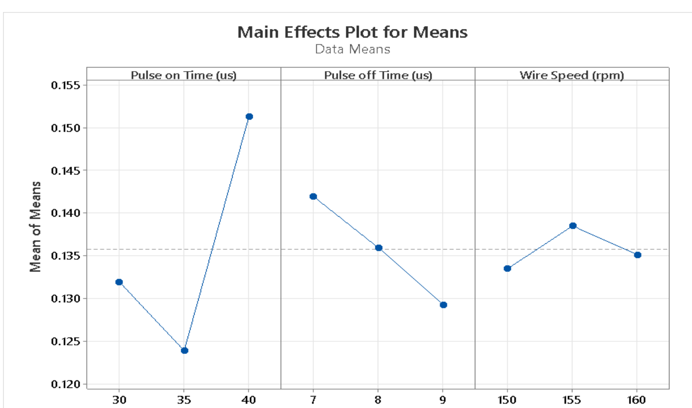

Fig.8. Main effect plots of material removal rate

In this graph is shown in fig 8 it shows that the material removal rate of the specimen is better when the pulse on time is 40μs and the pulse off time is 7µs and the wire speed is 155rpm. The roughness obtained by it was the optimum.

3.2 Tensile analysis:

The result obtained during the tensile test had been shown in fig:11.

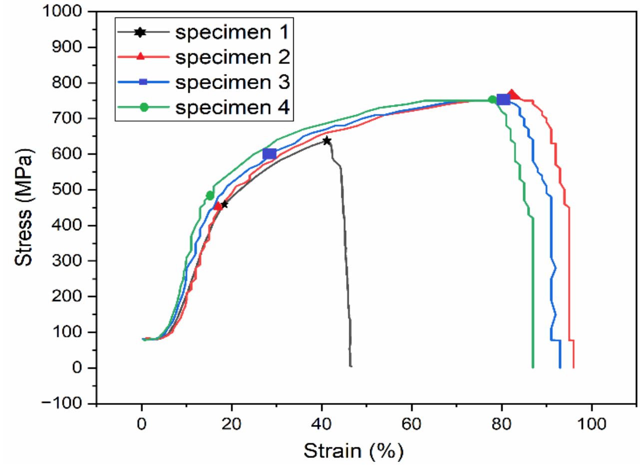

Fig. 9. Stress strain graph for the specimens

The stress strain graph of the tensile specimens shows the yield point of the of the tested specimens and also the ultimate tensile strength of the tested specimen was show in this fig 9.

3.2.1 Tensile Ansys:

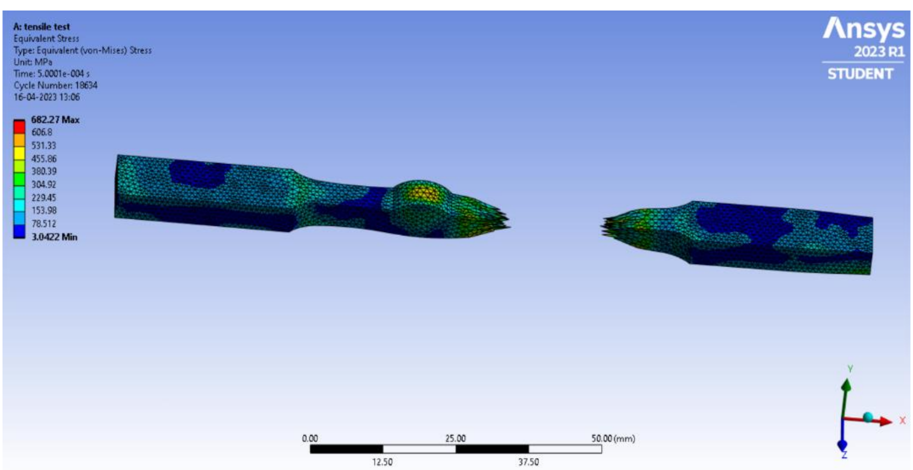

Fig.10. Stress obtained in the specimens

The stress obtained in the Ansys was 682.27 MPa is shown in the fig 10 whereas the tested specimen has the stress value as 750.500 MPa therefore, the stress obtained while testing of the specimen was increased so the mechanical tensile strength was ultimately increased.

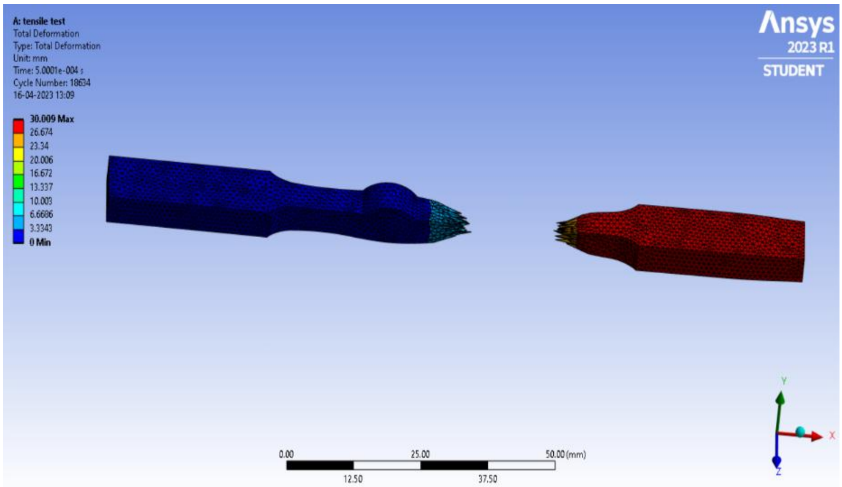

Fig.11. Total deformation for the specimens

The total deformation developed by the tensile specimen in the Ansys was is shown in the fig 11.

Table 7. Comparing the experimental and Ansys result.

Specimen	Material	Youngs modulus (GPa)	Poisson's ratio	Yield strength (MPa)	Ultimate tensile strength (MPa)
Experimental result	AISI 308	200	0.28	423.5	750.500
Ansys result	AISI 308	200	0.28	240	682.5

4 Conclusion

Using Taguchi analysis, experimental research on wire-cut electric discharge machining of AISI 308 alloy has been conducted. This inquiry took into account the machining parameters of pulse on time, pulse off time, and wire speed at various levels. In accordance with the Taguchi L9 orthogonal array, a number of experiments are conducted in order to find the ideal set of parameters. The conclusions are as follows.

- The ideal machining parameter combination to achieve the lowest surface roughness, according to Taguchi optimization approach, is Pulse on time (Ton) 35 (s), Pulse off time (Toff) 8 (s), and wire speed 155 (rpm).

- Similarly, the ideal machining parameter combination to achieve maximum Material removal rate is Pulse on time (Ton) 40 (s), Pulse off time (Toff) 7 (s), and wire speed 150 (rpm).

- In comparison to Ansys, the welded joint's tensile strength has increased. The experimental result for tensile strength is 750.500 MPa, but the tensile strength found in Ansys is 682.5 MPa for that material.

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