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An investigation into the parametric optimization of al 2219 using CNC wire EDM by using taguchi method

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Abstract
Optimization is one of the techniques used in manufacturing fields to arrive for the best manufacturing conditions, and essential need for industries for production of good products at cheap cost. This paper aims to investigate the optimal set of process parameter such as pulse on time, pulse off time and peak current in wire electrical discharge machining (WEDM) process to identify the variation in performance characteristic such as material removal rate (MRR) and surface roughness (Ra) value on the work material for machining Aluminium 2219 using brass electrode. Based on the experiment conducted on L9 orthogonal array, analysis has been carried out using ANOVA and Taguchi method. Response table and graphs were used to find the optimal levels of parameters in WEDM process. The confirmation experiments were done to validate the better results.

Keywords: WEDM, material removal rate, surface roughness, taguchi method

1. Introduction
In wire electrical discharge machining (WEDM), known as wire-cut EDM, a thin single-thread metal wire, mostly brass, is used to draw through the work piece, submerged in a tank of dielectric fluid, typically deionized water. Wire-cut EDM is mainly used to cut plates of thickness 300mm and to make punches, tools, and dies from harder metals which are difficult to produce with other methods. The wire, which is continously fed from a spool, is held between lower and upper guides which is centered in a water jet head. WEDM is commonly used when less residual stresses are desired, because it does not requires higher cutting forces for material removal. If the power per pulse is relatively less (As in finishing process), fewer changes in the mechanical properties of a material is expected due to these low tensile stresses, although material that hasn't been stress-relieved can distort in the machining process. The work piece may undergo a significant thermal cycle, its severity depending on the technological parameters used. Such cycles may lead to formation of a recast layer on the part and tensile stresses on the job. CNC Wire cut EDM machine puts impulse voltage between electrode wire and work piece through impulse force, controlled by servo system to get a certain gap, and realize impulse discharging in the working fluid between work piece and tool electrode. Number of tiny holes were appeared due to erosion of impulse discharging, and therefore required shape of work piece obtained.

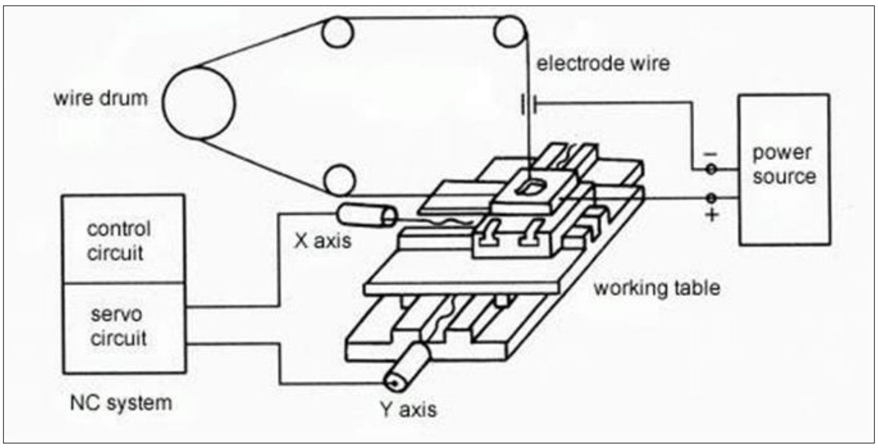

Fig 1: WEDM processes schematic representation

In Wire EDM a series of electrical pulses generated by the first generator unit is applied between the drawing wire electrode and the work piece, to cause the spark erosion of the conductive work piece material in the presence of an insulated di-electric fluid and these pulses create a very small discharge spark gap. Electrode wire is connecting to cathode of impulse power source, and work piece is connecting to anode of impulse power source. When work piece is approaching electrode wire in the insulating fluid and gap between them is getting small to a certain value, insulated fluid was broken through; very shortly, discharging channel forms, an electrical discharge happen. And release huge high temperature instantaneously, up to more than 10000 degree centi-grade, the eroded work piece is cooling down shiftly in working liquid and flushed away. Many sparks can be observed at one time, because actual discharges can occur more than hundred thousand times per second, with discharge sparks lasting in the range of 1/1000000 of a second or less. The amount of metal removed during the short time of spark discharge depends on the desired cutting speed and the surface finish simultaneous controlled movement of the working table in the X and Y axis allows parts to be cut to one or two tense (0.0001) accuracy routinely. The U and V axis are used to incline the upper portion of the wire when taper cutting is required. The Z axis controls the height portion of the upper guide.

2. Literature review

Mahapatra and Patnaik (2007) [1] conducted experiments on D2 tool steel using Taguchi's L27 orthogonal array. In their study six control factors considered were discharge current, pulse frequency, pulse duration, wire speed, wire tension and dielectric flow. MRR, surface finish and kerf were the performance measures chosen. Relationship between the control factors and responses are established by means of nonlinear regression analysis and then employed geometric algorithm to optimize the wire electrical discharging machining process with multiple objectives.

Y Chandrashekhar Reddy (2017), have presented a multi objective optimization of WEDM Machining Parameters of SS317 was performed using GRA analysis which converts the multi responses into a single grade. Taguchi based L9 orthogonal array is used for plan of experiments. The objectives chosen are the maximum material removal rate and minimum surface roughness using process parameters viz, Pulse ON Time, Pulse OFF Time and Peak Current. The optimal machining parameters results better quality and ANOVA.

B kuriachan (2014), reported a multi response optimization of Micro WEDM of Titanium alloy (Ti-6Al-4V) fuzzy logic and particles swarm optimization (PSO) algorithm. The effect of various parameters such as gap voltage, capacitance, feed rate and wire tension on the performance characteristic (MRR and Ra) of Micro EDM is studied. In their study they employed ANOVA to identify the significant factors.

Vineeth C and Dileeplal J on the year 2016 has experimented on process Parameter optimization of WEDM on Al2219 using Taguchi method. Their input parameters were pulse ON Time, Pulse OFF Time, Wire feed, Gap voltage and the corresponding output responses are MRR, Surface roughness and Kerf width.

Jerin Johnson, Bibin K T, Anoop Sankar on the year 2018 investigated on optimization of wire electric discharge machining parameters on Al6061. In this paper aims to investigate the optimal set of process parameters such as current, pulse on time, pulse off time, feed rate, wire tension in wire electrical discharge machining (WEDM) process to identify the variations in performance characteristics surface roughness value on the work material for machining Aluminium 6061 using brass electrode.

M Rafiraza on the year 2011 investigated on Development and Strengthening of Al2219 Aluminum alloy by mechanical working and heating. His result shows that maximum strength and hardness generally decrease at higher temperature with increasing aging time.

3. Experimental work

3.1 Workpiece material

Al 2219 is the material selected because it is the most significant and widely used material in the industries now a days. 2219 Aluminium alloy is an alloy in the wrought aluminium copper family. It can be heat treated to produce tempers with lower ductility and higher strength. The Aluminium copper alloy have high strength, but are generally less corrosion resistant and are harder to weldable than other types of aluminium alloys. Al 2219 is commonly used for the following:

- They are used in supersonic aircrafts skin [2]
- Widely used in automobile parts and space boosters [2]

Table 1: material composition of Al 2219

Material	Percentage
Aluminium	91.5 - 93.8
copper	5.8 - 6.8
Iron	0.3
Magnesium	0.02
Manganese	0.2 - 0.4
Silicon	0.02 - 0.10
Vanadium	0.05 - 0.15
Titanium	0.02 - 0.10
Zinc	0.1

3.2 Experimentation

The work material is acquired as a square piece of Aluminium 2219 whose measurements are 10 mm height, 10mm width and 20 mm length. Experiments are done on Electronica Ultra cut S1 Wire EDM machine.

Fig 2: WEDM Machine

After the experimentation, the MRR and surface roughness are calculated. L9 orthogonal array is used for the experimental design. Process parameters and their levels are shown in the table 1.

Table 2: Process parameters and levels

Sl. No	Factor	Unit	Symbols	Level1	Level2	Level 3
1	Pulse on time	Micro- seconds	A	100	110	120
2	Pulse off time	Micro seconds	B	50	55	60
3	Peak current	Ampere	C	10	11	12

The designed matrix of input parameters and the output parameters are shown in the table 2.

Table 3: L9 mixed array design based on Taguchi's method

	Pulse on time	Pulse off time	Peak current	MRR	Ra
1	100	50	10	0.10	1.82
2	100	55	11	0.08	2.46
3	100	60	12	0.08	2.66
4	110	50	11	0.09	3.94
5	110	55	12	0.11	3.66
6	110	60	10	0.08	1.64
7	120	50	12	0.13	3.70
8	120	55	10	0.12	1.86
9	120	60	11	0.09	4.14

4. Results and Discussions

4.1 Effect of input parameter on MRR

The WEDM machining experiments were conducted by using the parametric approach of the Taguchi method the effect of individual WEDM machining process parameters on the material removal rate. The mean value an S/N ratio of response characteristics for each variable at different levels are obtained from experimental data.

Table 4: Effect on material removal rate

Level	Pulse on time	Pulse off time	Peak current
1	-21.29	-19.55	-20.12
2	-20.68	-19.84	-21.26
3	-19.02	-21.60	-19.61
Delta	2.27	2.05	1.65
Rank	1	2	3

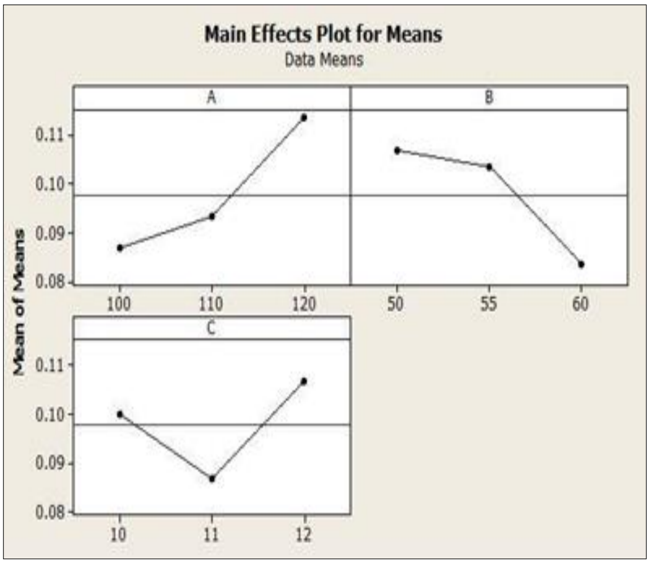

Fig 3: Main effect plot for mean for MRR

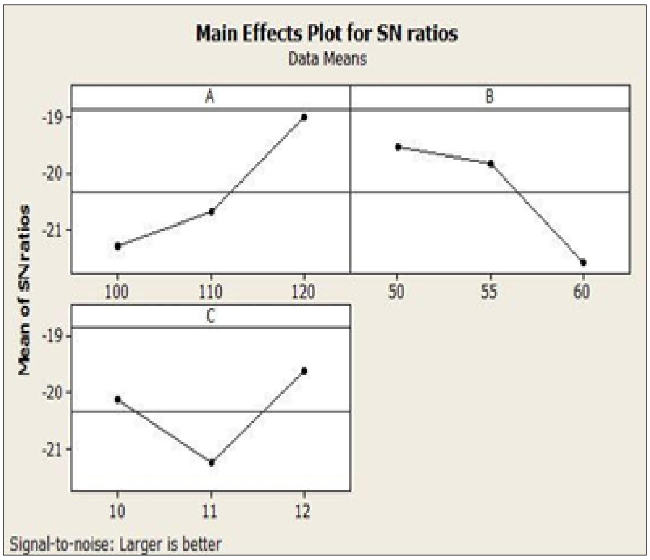

Fig 4: Main effects plot for S/N ratio for MRR

From Table 4 we found that the material removal rate is most influenced by Pulse on time then by pulse off time and least effected by peak current.

From the below graph we can identify the optimal combination, which is A3, B1, C3.

- A3 Corresponds to pulse on time= 120 micro meters
- B1 Correspond to Pulse off time= 50 micro meters
- C3 Corresponds to Peak current= 12A

Mathematical modelling for MRR,

MRR = 0.0428 + 0.00133 A – 0.00233 B + 0.00333 C

MRR = 0.0428 + 0.00133(120) – 0.00233(50) + 0.00333(12) the regression equation obtained from optimal combination: MRR= 0.1258 mm3/min

4.2 Effect of input parameter on Ra

The WEDM machining experiments were conducted by using the parametric approach of the Taguchi method the effect of individual WEDM machining process parameters on the surface roughness.

The mean value an S/N ratio of response characteristics for each variable at different levels are obtained from experimental data.

Table 5: Effect on surface roughness

Level	Pulse on time	Pulse off time	Peak current
1	-7.173	-9.492	-4.963
2	-9.159	-8.160	-10.690
3	-9.698	-8.378	-10.377
Delta	2.526	1.332	5.727
Rank	2	3	1

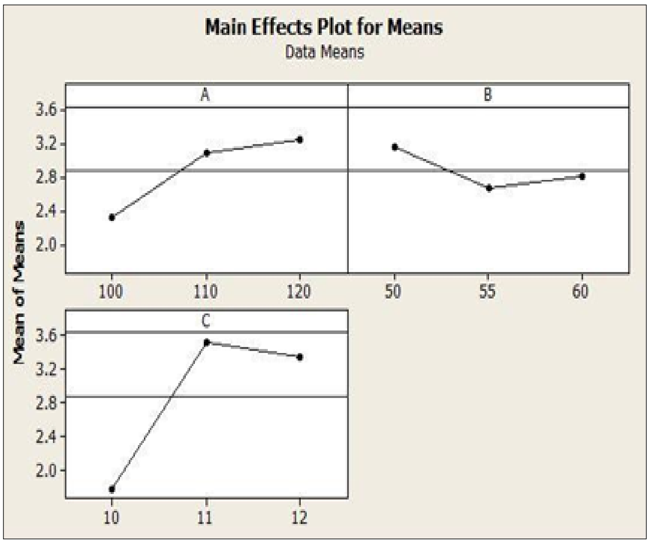

Fig 5: Main effects plot for means for Ra

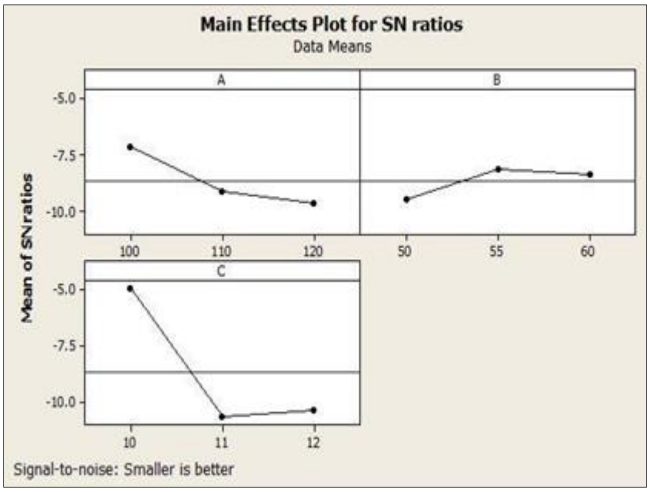

Fig 6: Main effect plot for S/N ratio for Ra

From table 5 we found that surface roughness is most influenced by peak current then by pulse on time and least effected by pulse off time. From the below graph we can identify the optimal combination, which is A1, B2, C1.

- A1 Corresponds to pulse on time= 100 micro meters
- B2 Correspond to Pulse off time= 55 micro meters
- C1 Corresponds to Peak current= 10A

Mathematical modelling for Ra

The regression equation in terms of coded factors is given by, Ra = -8.93 + 0.0460 A – 0.0340 B + 0.783 C

Ra = -8.93 + 0.0460(100) – 0.0340(55) + 0.783(10)

The regression equation obtained from optimal combination: Ra= 1.63 µm. So the predicted value for Ra is 1.63 µm. Now by using the above obtained combination of parameters (A1, B2, C1) we conducted a confirmatory experiment and the corresponding Ra value is observed. Similarly the predicted value for MRR is 0.1258 mm3/min and corresponding to the optimal parameter (A3, B1, C3) confirmatory experiment for MRR is also observed.

Table 6: Confirmatory experimental values

Parameter	Predicted	Experimental
Ra	1.63	1.7
MRR	0.125	0.128

5. Conclusion

In the presented work, experiments are carried out for MRR and Surface roughness with variables as Pulse on time, pulse off time and peak current. Based on the experimental analysis carried out by conducting WEDM on Al 2219 alloy using L9, the following points were observed:

- Most significant parameter affecting Ra is peak current.
- Most significant parameter affecting MRR is pulse on time.
- Least significant parameter affecting Ra, MRR are pulse off time.
- Optimal combination of MRR using S/N ratio was found to be peak current 12A, pulse on time 120 µs, pulse off time 50 µs.
- Optimal combination of Ra using S/N ratio was found to be peak current 10A, pulse on time 110 µs, pulse off time 55 µs.

6. References

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