RESEARCH ARTICLE

SAMRIDDHI Volume 14, Issue 1, 2022 Print ISSN: 2229-7111 Online ISSN: 2454-5767

Modeling of Surface Quality and Wire Offset during WEDM of Die Steel D3

Ramesh K. Verma[1], Rajeev K. Upadhyay[2], Syed A. H. Rizvi[3]*

[1]Maharishi University of Information Technology, Lucknow, UP, India

[2]Hindustan College of Science and Technology, Mathura, UP, India

[3]Khwaja Moinuddin Chishti Language University, Lucknow, UP, India

Abstract

The present model portrays the quality of surface machined and wire offset during wire-EDM of Die Steel D3 using zinc-coated brass wire. Taguchi approach is employed, and the orthogonal array was developed using peak current, pulse on duration, and wire tension as the machining parameters. Dependency of wire EDM factors over surface roughness and wire offset was assessed. It was found that the roughness of the machined surface is majorly controlled by on duration of the pulse. For wire offset, the current is the crucial electrical parameter. Higher intensity sparks induce a dimensional shift in the work.

Keywords: SEM, Surface Roughness, WEDM, Wire offset.

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology (2022); DOI: 10.18090/samriddhi.v14i01.10

Corresponding Author: Syed Asghar Husain Rizvi, Khwaja Moinuddin Chishti Language University, Lucknow, UP, India, e-mail: sahr.me@gmail.com

How to cite this article: Verma, R.K., Upadhyay, R.K., Rizvi, S.A.H. (2022). Modeling of Surface Quality and Wire Offset during WEDM of Die Steel D3. *SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology,* 14(1), 61-65.

Source of support: Nil

Conflict of interest: None

Introduction

Die Steel D3 is steel with high chromium carbon, excellent abrasion resistance, and good size precision with higher compressive strength. It is extensively used in dies, forming rolls, press tools, and punches. The conventional machining of Die Steel D3 is difficult. Wire-Electric Discharge Machine (Wire-EDM) is among the other promising machining techniques used to cut hard materials and complex contours of dies and tools. The surface quality and dimensional offest are the performance estimate that majorly influences the quality of dies and tools produced.

The pulse on and pulse off duration and spark voltage are pivotal parameters for surface roughness.[1] In another investigation, surface roughness was found to have direct influence with pulse on time. Pulse on duration was detected as the most influencing factor of surface roughness produced it is notice to have an increasing trend with pulse on duration due to production of broader and deeper crater. They also concluded that the voltage has negligible influence on surface roughness.[2] In an investigation, the parameters selected were speed, feed, pulse on duration and pulse off time and all the parameters were found to have a crucial influence on surface roughness.[3]

In another research it was found that the machined roughness escalates with pulse current and on time of pulse resulting because of higher discharge energy. Moreover, at lower level of electrical parameters, the dimensional shift was perceived to be high.[4] The parameter pulse duration was observed to be the most efficient towards surface quality which is accompanied by the peak current while the least influencing parameter was found as wire speed.[5]

It was also observed that the pulse on duration has key dominance on surface quality while the pulse duty factor is least influencing parameter.[6] The coarseness of the machined surface increases with increase in current. Bed speed, also influence the surface roughness and at higher bed speed higher surface unevenness level is accomplished. For achieving better surface finish, low value of current and bed speed must be employed.[7] It is also noticed that wire feed rate majorly dominates surface roughness. Wire feed falls to be the utmost decisive parameter followed by pulse off duration and pulse on duration.[8]

The literature survey divulged that the surface roughness of the work is predominantly influenced by on duration and pulse current and the offset accuracy is independent of the electrical parameters and is indeed influenced by flushing nozzle height, workpiece height and corner angles.[9]

In another investigation, it was discovered that by increasing pulse duration, voltage and wire speed, the surface roughness will increase. On the other hand, on increasing the pressure of dielectric fluid, the surface roughness decreases.[10]

The present research aims to model the surface roughness and wire offset during wire-EDM of die steel D3 using Taguchi approach. L9 orthogonal array is employed for regulating the experiments on Wire-EDM.

Experimental Procedure

The work for the present research was performed on the Electronica Maxicut Wire-EDM machine while kerosene is used as the dielectric medium. Die Steel D3 is used as a workpiece which is a machine by brass wire with zinc coating having 0.25mm diameter. Taguchi approach is employed, and an L9 orthogonal array is developed to conduct the experiments using peak current, pulse on duration, and wire tension as the machining factor for assessing surface quality and wire offset during machining. The properties and elemental composition of Die Steel D3 are shown in Tables 1 and 2.

The surface unevenness was gauged by Mitutoyo surface roughness tester while the offset was measured employing scanning electron microscopy (SEM). Figure 1 shows the arrangement of workpiece during machining.

The Mitutoyo surface roughness tester gauged the surface unevenness while the offset was measured employing scanning electron microscopy (SEM). Figure 1 shows the arrangement of the workpiece during machining.

Wire offset arises due to the force generated by electro-discharge during cutting, making electrode wire bend and diverge the small distance. Due to this force, the deviation induces a measurement shift in the profile to be produced. Dimensional shift (DS) is the normal extent between the actual machined job profile from the programmed path in the first cut with zero wire offset setting. This is known as the Wire offset for the first cut. Wire offset for rough cutting is

Figure 1: Matching of Die Steel D3 on Electronica Maxicut Wire EDM

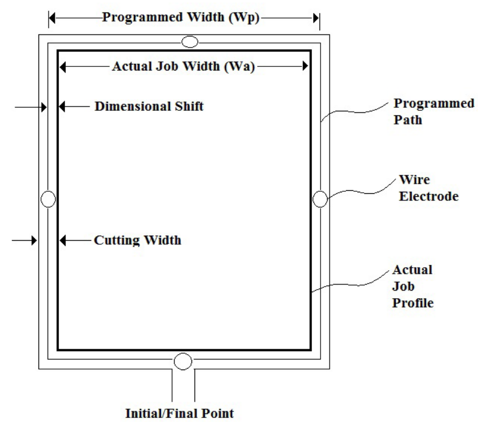

Figure 2: Illustration of Dimensional Shift during machining

Table 1: Properties of Die Steel D-3

Density (g/cm^3)	*Melting point (°C)*	*Yield strength (MPa)*	*Elastic modulus (GPa)*	*Poisson's ratio*	*Brinell hardness*
7.87	1421	470	190	0.28	215

Table 2: Chemical composition of the work (DIE STEEL D-3) by weight

Material	*Fe*	*Ni*	*Mn*	*Cr*	*C*	*Si*	*Cu*	*V*	*Mo*
% Composition	86.58	0.0689	0.269	11.05	2.07	0.191	0.00367	0.0218	<0.002

Table 3: Experimental details and SN Ratio of performance measures

Exp. No.	*Peak current (A)*	*Pulse on time (μsec)*	*Wire tension*	*Wire offset (mm)*	*Surface roughness (μm)*	*SN ratio of wire offset*	*SN ratio of surface roughness*
1	2	4	400	0.013	6.78	37.721	-16.625
2	2	6	700	0.0485	7.04	26.285	-16.952
3	2	8	1000	0.0455	8.72	26.84	-18.81
4	4	4	700	0.0485	7.97	26.285	-18.029
5	4	6	1000	0.018	8,25	34.895	-18.329
6	4	8	400	0.0655	9,16	23.675	-19.238
7	6	4	1000	0.0525	6.21	25.597	-15.862
8	6	6	400	0.079	8.78	22.048	-18.87
9	6	8	700	0.0835	9.82	21.566	-19.842

equal to DS. The dimensional shift is shown in Figure 2. The Table 3 shows the details of experiments and the SN ratio for performance measures.

Dimensional Shift = 0.5 (Programmed width – actual job Width)

Experimental Results

Surface Roughness

For the existing model, the surface roughness lies between 6.21 µm to 9.82 µm. The tests show that the on duration is the most decisive factor for surface roughness while current is the second most dominating factor.

Table 4 shows that the influence of the present set of parameters is in the order of pulse on duration > peak current > wire tension. ANOVA performed on the model is expressed in Table 5. Through ANOVA, the contribution of WEDM parameters is assessed, and it is clear that pulse on duration is the only factor that greatly influences the surface quality of Die Steel D3 while peak current possesses little dominance over it. The contribution of pulse on time is 66.53%. In the case of wire tension, it almost has negligible influence on surface roughness.

Table 4: Mean S/N Ratio for Roughness of Surface

Level	*Peak Current (A)*	*Pulse on time (µsec)*	*Wire Tension*
1	-17.46	-16.84	-18.24
2	-18.53	-18.05	-18.27
3	-18.19	-19.30	-17.67
Delta	1.07	2.46	0.60
Rank	2	1	3

Through the main effect plot in Figure 3, it is established that the roughness of the machined surface increases with an increase in the level of pulse on duration. Ton directly influences the surface roughness as the spark intensity depends upon it. An enormous crater is the basis of the poorer surface quality of Die Steel D3. Moreover, for peak current, roughness initially increases up to 4A, but later on, further increase in its level, the surface roughness gets reduced. Further, when wire tension is considered, the surface roughness is almost constant at 400 and 700, yet it starts to decline with an increase in the level of wire tension.

Wire Offset

The wire offset during the present set of parameters lie between 0.013 mm to 0.0835 mm. it is detected through the experiments that the magnitude of offset induced in the job because of dimensional shift is majorly influenced by peak current followed by pulse on time. The dominance of wire tension seems minimal towards wire offset for the present level of parameters.

Table 6 elucidates that the effectiveness of the parameters is in the order peak current > pulse on-time > wire tension. From ANOVA in Table 7, peak current is found to be a majorly influencing parameter and contributes 46.07% towards wire offset. It is the key factor for this model. It is followed by pulse on duration having a contribution of 23.72% towards wire offset. Wire tension is the least dominating parameter.

The main effect plot in Figure 4 elucidated that the wire offset increases with the rise in current and pulse on duration. They are the electrical parameters and hence influence directly towards the offset as they directly affect the spark intensity. The higher the intensity of the spark, the more will be the dimensional shift. For wire tension, the wire offset

Table 5: ANOVA for Surface Roughness

Source	*DOF*	*SS*	*Adj MS*	*F Value*	*% Contribution*
Peak current	2	1.5048	0.7524	0.86	13.20
Pulse on time	2	7.5863	3.7932	4.35	66.53
Wire tension	2	0.5674	0.2837	0.33	4.98
Error	2	1.7446	0.8723		15.30
Total	8	11.4031			100

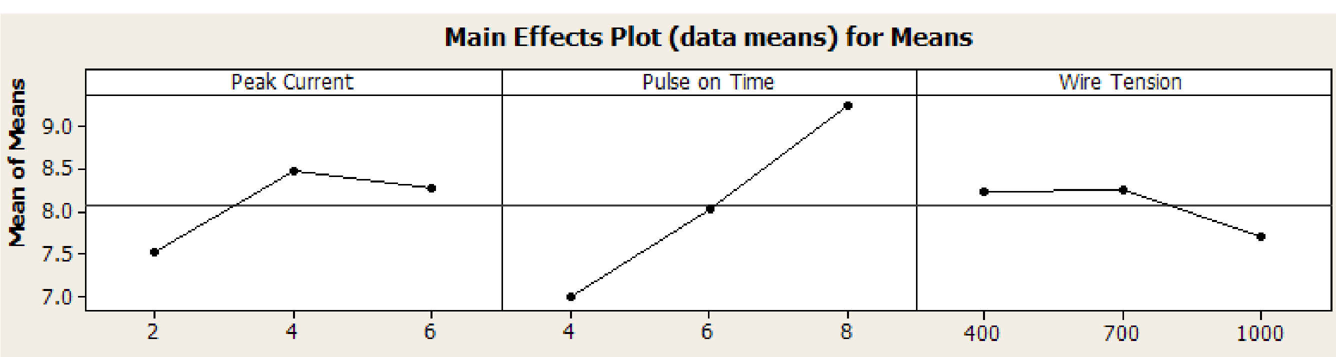

Figure 3: Main effect plot for Surface Roughness

Table 6: Mean S/N Ratio for Wire Offset

Level	*Peak current (A)*	*Pulse on time (µsec)*	*Wire tension*
1	30.28	29.87	27.81
2	28.28	27.74	24.71
3	23.07	24.03	29.11
Delta	7.21	5.84	4.4
Rank	1	2	3

Table 7: ANOVA for wire offset

Source	*DOF*	*SS*	*Adj MS*	*F Value*	*% Contribution*
Peak current	2	0.00213	0.00107	3.11	46.07
Pulse on time	2	0.00110	0.00055	1.60	23.72
Wire tension	2	0.00071	0.00036	1.04	15.40
Error	2	0.00069	0.00034		14.82
Total	8	0.00463			100

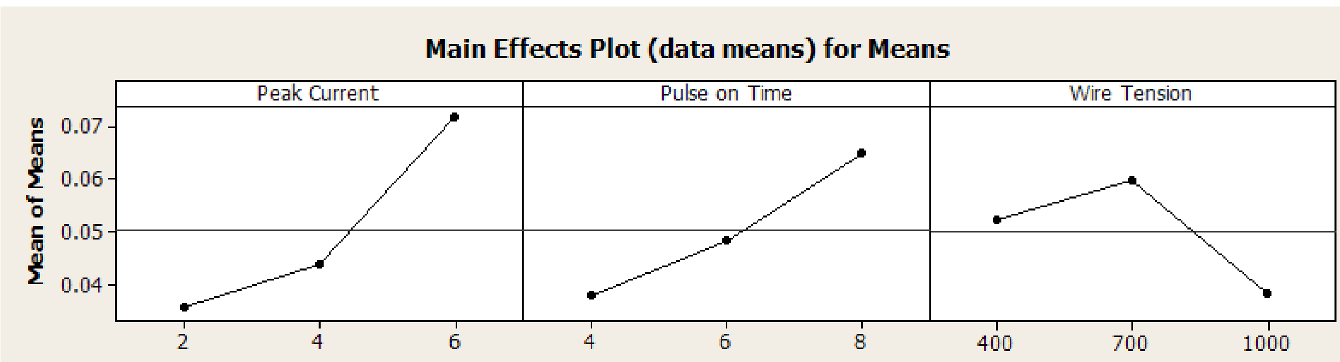

Figure 4: Main effect plot for Wire Offset

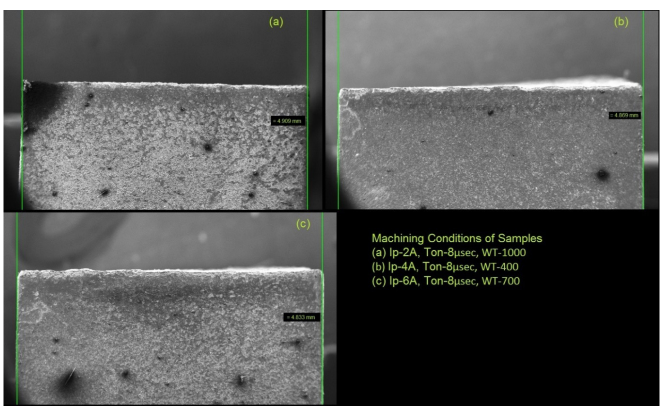

Figure 5: SEM images for dimensional shift measurement (a) Sample 3 (b) Sample 6 (c) Sample 9

initially increases up to 700 and then tends to reduce. This is the end result of the rise in the tension of the wire offers stiffness to it and thus avoids dimensional shift.

Figure 5 on the previous page shows the SEM images of Wire-EDMed specimens (a) sample 3, (b) sample 6, and (c) sample 9. The linear measurement tool of the Carl Zeiss EVO 50 SEM machine is used to estimate the machined width of actual job width obtained after machining. This is then compared with the programmed with to calculate the degree of offset or dimensional shift induced in the workpiece.

Conclusion

This effort gives out the experimental modeling of parameters during Wire EDM of Die Steel D3. Using the Taguchi approach, experiments for the rough cutting operation were performed to model peak current, pulse on duration, and wire tension for surface roughness and wire offset.

The measure of surface unevenness is within the range of 6.21 µm to 9.82 µm, while that of the offset is in the range of 0.013 mm to 0.0835 mm for the present model. Using ANOVA, it was found that pulse on duration has utmost dominance on surface roughness while the tension of wire was the least dominating factor. From the SEM images, the evaluated figures of wire offset were assessed, and analysis of variance for this performance measure revealed that peak current is the crucial factor while wire tension has the least influence on wire offset.

Based on the present model, a minimum level of current and on time are suggested to achieve a better surface finish and minimal dimensional shift. On the other hand, higher values are adopted to enhance surface quality and lower the wire offset while considering wire tension. It is also concluded that spark intensity is high at a higher level of electrical parameters. Hence wire offset is directly influenced. For higher wire tension, the stiffness of the wire increases and reduces the level of the dimensional shift of the specimen.

References

[1] Bobbili R., Madhu V., and Gogi A.K. (2013). Effect of Wire-EDM Machining Parameters on Surface Roughness and Material Removal Rate of High Strength Armor Steel. *Materials and Manufacturing Processes*, 28, 364-368.

[2] Gajjar D.H., Desai J.V. (2015). Optimization of MRR, Surface Roughness and KERF Width in wire EDM Using Molybdenum Wire. *International Journal for Research in Education,* 4, 9-17.

[3] Kumar K., Ravikumar R. (2013). Modeling and Optimization of Wire EDM Process *International Journal of Modern Engineering Research*, 3, 1645-1648.

[4] Kumar V., Kumar V., Jangra K.K. (2015). An experimental analysis and optimization of machining rate and surface characteristics in WEDM of Monel-400 using RSM and desirability approach. *J Ind Eng Int*, 11, 297–307.

[5] Kurian A.M., Yeldose B.C., Mathew E.M. (2014). Effect of Wire EDM Parameters on Surface Roughness of Stainless Steel 15-5 PH, *International Journal of Engineering and Innovative Technology*, 4, 87-90.

[6] Malik M., Yadav R.K., Kumar N., Sharma D., (2012). Optimization of process parameters of wire EDM using zinc-coated brass wire. *International Journal of Advanced Technology & Engineering Research*, 2, 127-131.

[7] Marigoudara R.N., & Sadashivappa K. (2013). Effect of Machining Parameters on MRR and Surface Roughness in Machining of ZA43/ SiCp Composite by WEDM. *International Journal of Applied Science and Engineering*, 11, 317-330.

[8] Nagaraja R., Chandrasekaran K., Shenbhgaraj S. (2015). Optimization of parameters for metal matrix composite in Wire-EDM. *IJESRT*, 4, 570-574.

[9] Selvakumar G., Sarkar S., & Mitra S. (2012). Experimental investigation on die corner accuracy for wire electrical discharge machining of Monel 400 alloy. *Proc IMechE Part B: J Engineering Manufacture*, 226, 1694–1704.

[10] Tosun N., Cogun C., and Inan A. (2003). The Effect of Cutting Parameters on Workpiece Surface Roughness in Wire EDM. *Machining Science and Technology,* 7, 209-219.