International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 13s,2025
https://theaspd.com/index.php`

Design And Optimization Of Wire-Electrochemical Discharge Machining (W-EDM) Process Based On Vibration System Detector On Material Variations By Particle Swarm Optimization Algorithm Method

Eli Novita Sari[1], Chairul Anam[2], Mahros Darsin[3]
[1]Manufacturing Engineering Technology, Department of Mechanical Engineering, Banyuwangi State Polytechnic, Banyuwangi, Indonesia.
[2]Manufacturing Engineering Technology, Department of Mechanical Engineering, Banyuwangi State Polytechnic, Banyuwangi, Indonesia.
[3]Mechanical Engineering, Department of Mechanical Engineering, University of Jember, Jember, Indonesia.
[1]eli.novitasari@poliwangi.ac.id, [2]anam@poliwangi.ac.id, [3]mahros.teknik@unej.ac.id

Abstract: *Vibration analysis is one way that industrial machine maintenance can be done quickly and conveniently. A pattern of sound is produced by engine vibrations in which the sounds of several engines are mixed together. Engine component damage is indicated by excessive vibration levels in the engine. The machine will sustain more significant harm if nothing is done about this high vibration. The machine has to be maintained in order for it to function at its best. In order to prolong machine life, machine maintenance systems are crucial in the industrial sector. Vibration-signal-based predictive maintenance is one often employed maintenance technique. One form of maintenance that can be performed by keeping an eye on the vibration conditions the machine is producing is called predictive maintenance. Predictive maintenance based on vibration cues is one often employed maintenance technique. One kind of maintenance that can be done is predictive maintenance, which involves keeping an eye on the vibration conditions that the machine produces. Analyzing the machine's vibration level as represented by the vibration speed's amplitude value is one technique to prevent damage to the device. By using the vibration signals that arise, this technology can predict machine damage and prevent major damage. The research combined the two outputs of vibration detection and process optimization to create a prototype Wire-Electrochemical Discharge Machining (W-EDM) machine. The goal of this study is to identify and ascertain the parameter values that yield the best possible result. Full factorial, orthogonal array, and response surface approach are the experimental designs employed, and back propagation neural network and particle swarm optimization algorithm are the optimization techniques.*
Keywords: Wire-Electrochemical Discharge Machining, material variation, vibration, detector, algorithm

Introduction:

The term Wire-Electrochemical Discharge Machining (W-EDM) refers to a hybrid/hybrid machining process that consists of two parts: the electrochemical machining (ECM) and the listrik machining (EDM) [1]. Research on the Wire-Electrochemical Discharge Machining (W-EDM) process has been conducted by a few researchers, with an emphasis on the material/work bend type, electrochemical machining, machining quality, and electrode/paper characteristics [2]. The Wire-Electrochemical Discharge Machining (W-EDM) process is a complex procedure that yields numerous significant process parameters [3]. The process parameters, tool, material, and electrochemical silica maintain an important role in the quality characteristics of the Wire-Electrochemical Discharge Machining (W-EDM) process [4]. The permeation parameters are feed rate, polarity, duty cycle, current, voltage, and gaps between electrodes. Material properties of chisels and electrolytes consisting of chisel material, geometry chisel, electrolyte type [5-6]. Emphasis is placed on the qualitative aspects of the study, including material properties, surface roughness, tool wear ratio, and research on the application of Wire-Electrochemical Discharge Machining (W-EDM) to understand the development and creation of W-EDM setups based on Arduino [7-8]. Drawings in two dimensions are created using AutoCAD software, while three-dimensional models are created using CATIA software [9]. The Wire-Electrochemical Discharge Machining (W-EDM) prototype is manufactured accurately using 2D and 3D models, and experimental work is done on the material-processing process using micro-hole drills on non-conductive materials [10]. The results indicate that the length of time spent on material preparation and finishing increases with the increase in volt and electron density [11]. Industrial machinery with a rotating function frequently vibrates [12]. The sound of one engine blending with the sound of another is a pattern of sound that is produced by engine vibrations [13]. Variations in engine vibration will lead to variations in the engine's sound signature [14]. High engine vibration levels are a sign of engine component damage. The machine will sustain more significant damage if nothing is done about this high vibration [15]. Maintenance is necessary for the machine to function at its best. To increase a machine's lifespan in the industrial setting, the machine maintenance system is crucial. Predictive maintenance based on vibration cues is one often employed maintenance technique . One form of maintenance that can be performed by keeping an eye on the vibration conditions that the machine is producing is called predictive maintenance . Predictive maintenance based on vibration cues is one often employed maintenance technique. One kind of maintenance that can be done is predictive maintenance, which involves keeping an eye on the vibration conditions that the machine produces. Analyzing the machine's vibration level as represented by the vibration speed's amplitude value is one technique to prevent damage to the device. It is possible to determine whether or not the machine's bearings are suitable for usage by monitoring the vibration level readings . Vibration signals can be used to identify issues or types of machine damage, such as imbalance, looseness, misalignment, and bearing damage. By using the vibration signals that arise, this technology can predict machine damage and prevent major damage.A computer directly controls the program that is used by the W-EDM operating system. Generally speaking, the mechanic and computer work in tandem to construct Wire-Electrochemical Discharge Machining (W-EDM) machines and their operating system [16]. This machine tool, called Wire-Electrochemical Discharge Machining (W-EDM), operates on the X, Y, and Z axes. This Wire-Electrochemical Discharge Machining (W-EDM) machine is outfitted with a system control and will operate in accordance with the workpiece drawing pattern [17]. This Wire-Electrochemical Discharge Machining (W-EDM) machine is controlled by a number of interconnected components that are connected to one another via cables [18]. The computer, breakout board, motor driver, stepper motor, and other crucial parts of the Wire-Electrochemical Discharge Machining (W-EDM) control system are The computer, breakout board, motor driver, stepper motor, and power supply are all part of the control system. increased wear rate with load application [19].

METHODS AND METHODOLOGY:

The irregularity of the surface configuration on an object or plane is known as surface roughness. This happens as a result of different variations that arise throughout the machining process, making it impossible to generate a surface with an exact shape. Figure displays the location of Ra, the profile shape, the sample length, and the measurement length that the surface roughness measuring device read.

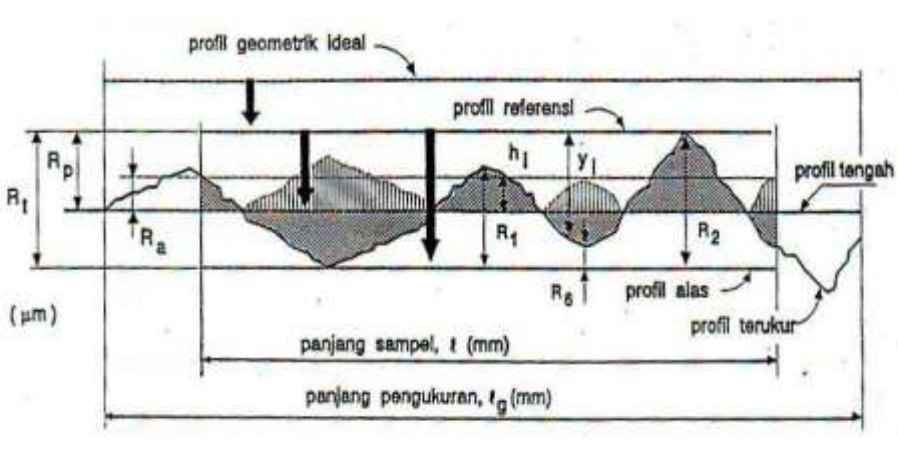
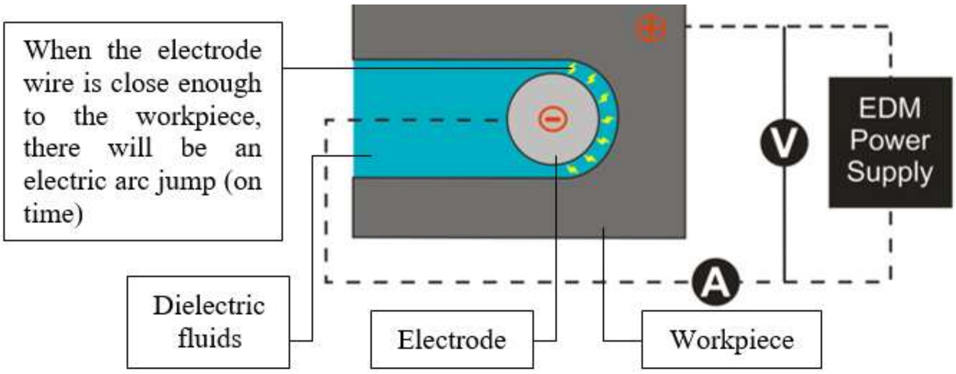


Figure 1 Profile roughness parameter [5]

The unevenness of a surface configuration on a plane or object is called surface roughness. This is because, as a result of several irregularities that arise during the machining process, a perfectly shaped surface cannot be produced. Figure displays the location of Ra, profile shape, sample length, and measurement length as read by the surface roughness measuring device.The mass and elasticity of all mechanical systems allow them to move relative to one another, which is why vibrations occur in practically all machine tool configurations. Back and forth motion within a predetermined time frame is called vibration. Periodic movement is defined as oscillating back and forth over a predetermined length of time. Because this periodic movement can always be represented as a sine or cosine function, periodic movement is also known as harmonic movement. Figure 1 depicts a harmonic periodic motion example in the time domain. Time is shown in the horizontal direction, whereas displacement is shown in the vertical direction. The W-EDM process can be seen in the following figure 2.



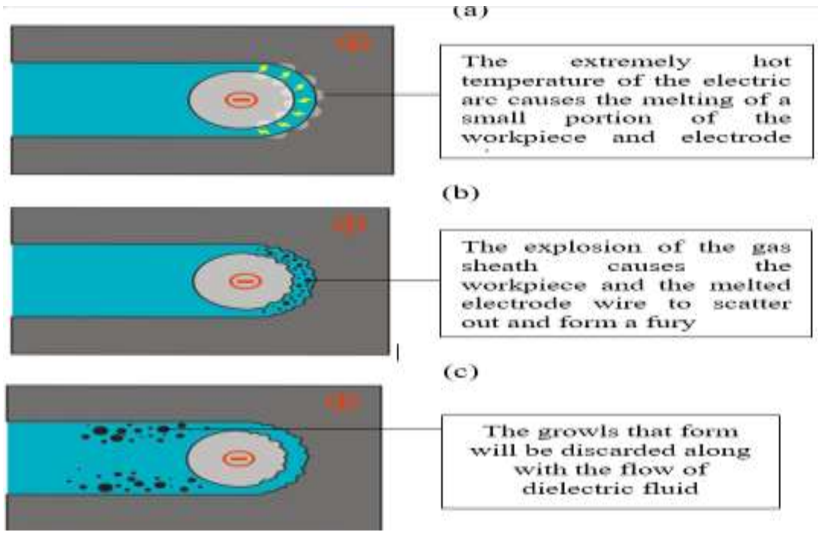


Figure 2 W-EDM process and Cutting Illustration

RESULTS:

Surface roughness measurement data and vibration level amplitude values are the outputs of the cutting test data. Experiments were conducted on aluminum material utilizing the W-EDM method and a carbide tool with six different diameters for spindle rotation and depth of cut. The vibration level amplitude data for the surface roughness data are displayed in Figure 1 as the results. The values for the rms (root mean square) vibration calculation data in the time domain will be the same as calculations in the frequency domain. The time domain is utilized to calculate the peak and peak to peak vibration values. The largest vibration value is known as the peak amplitude, and the overall amplitude value from the vibration's positive point to its negative point is known as the peak to peak amplitude. The accompanying figure shows examples of vibrations in the frequency and time domain during the flat grinding process, with cutting depth parameters of 0.3.0.4.0.5 mm and spindle rotation of 2000, 3000, 4000, 5000, and 6000 rpm. The amplitude display can be seen in the image figure 3 and figure 4

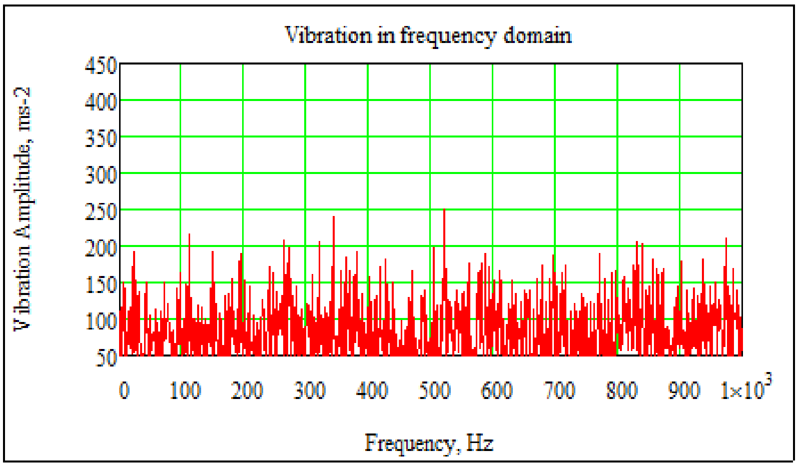


Figure 3 Vibrations in the Time domain

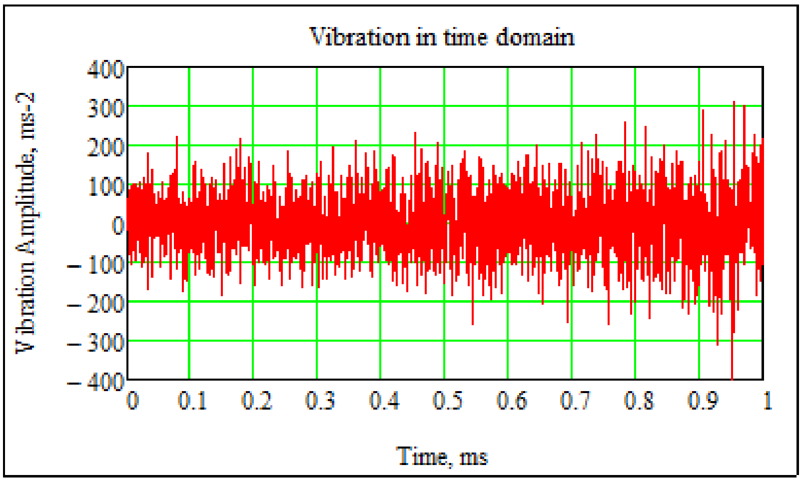


Figure 4 Vibrations in the Frequency Domain

Three different cutting depths (0.3, 0.4, and 0.5 mm) and four different spindle rotations (2000, 3000, 4000, 5000, and 6000) were used in the research tests. The surface roughness is measured and vibration is tested using these machining process factors. Using mathCAD, the accelerometer's measurement data are computed using the following formulas for rms, peak, and peak to peak on each x- and y-axis. An accelerometer, power supply, computer, Picotech ADC (analog to digital converter), Wire-Electrochemical Discharge Machining (W-EDM), and surface roughness test comprise the experimental apparatus. The carbide SKD 11 tool, measuring 300 x 60 x 1 mm, is the workpiece that was utilized. The spindle rotation, which is calculated to be (2000, 3000, 4000, 5000) (rpm), is the process variable. Cut depths: 0.3 mm, 0.4 mm, and 0.5 mm. Average surface roughness (Ra) (µm) and vibration level (g.rms) are the response variables. In order to monitor vibration during cutting tests, two accelerometers (sensors at positions A and B) are installed on the workpiece in the x- and z-axis directions (channels A and B), and they are connected to an ADC (Analog to Digital) Converter and a power source.Adjust process variables such cross feed speed and cut depth. After that, a cutting test is run on every possible combination of process variables, yielding cutting data that is saved on the computer as an amplitude. After the data is processed in mathCAD software to produce the time domain, the fast Fourier transform (FFT) formula is used to turn the FFT into a frequency domain. It is possible to observe the cutting test plan used to determine vibration amplitude values. The display of the trial schema can be seen in Figure 5 below.

Figure 5 experimental scheme

Table 1. Data

voltage (voltage)	current (ampere)	Amplitude		Ra max. Axis direction x	Ra max.Axis direction z
		axis x (A) m/s^2	axis z (B) m/s^2		
6	A = 2	183,7417	188,1417	0,33	0,36
	A = 4	286,0418	266,6726	0,43	0,40
	A= 6	346,4123	337,6609	0,52	0,48
8	A = 2	242,8280	246,7232	0,55	0,53
	A = 4	339,6239	316,7831	0,63	0,64
	A= 6	385,3925	403,2435	0,71	0,74
10	A = 2	297,4235	291,2057	0,67	0,69
	A = 4	427,7960	360,5500	0,78	0,81
	A= 6	459,7460	454,2341	0,89	0,98
12	A = 2	337,6735	325,4557	0,76	0,73
	A = 4	492,2763	432,9695	1,05	1,05
	A= 6	577,0734	531,1888	1,19	1,16
14	A = 2	422,4194	414,0373	0,96	0,99
	A = 4	586,2794	561,3089	1,35	1,22
	A= 6	650,0344	592,1781	1,41	1,42

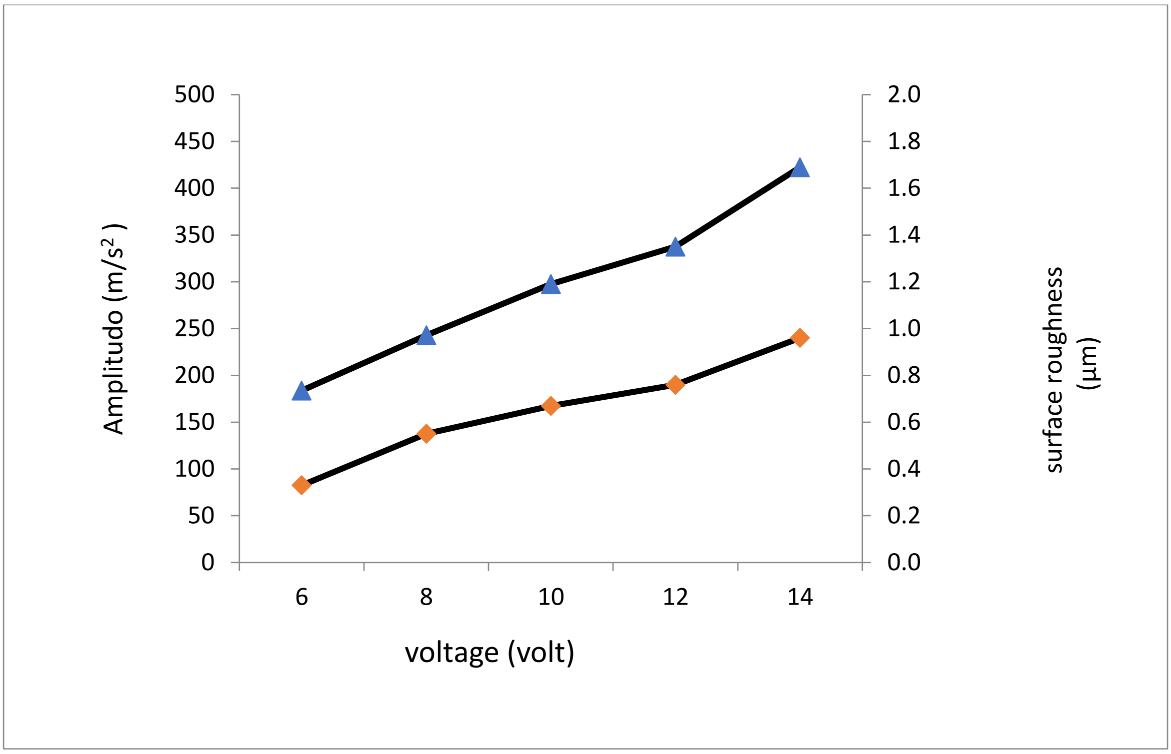


Figure 6 The relationship between amplitude, voltage, and surface roughness at peak amplitude on the x-axis for a current of 2 A

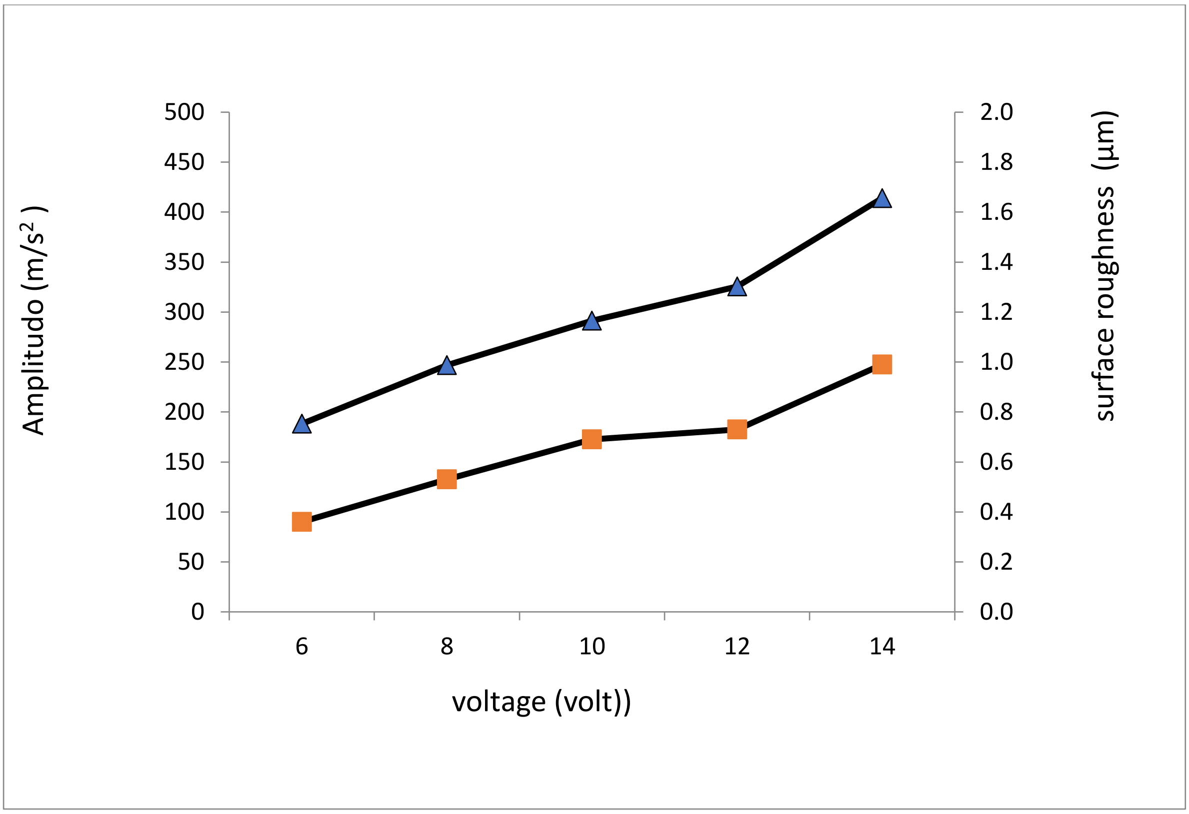


Figure 7 The relationship between amplitude, voltage, and surface roughness at peak amplitude on the *z*-axis for a current of 2 A

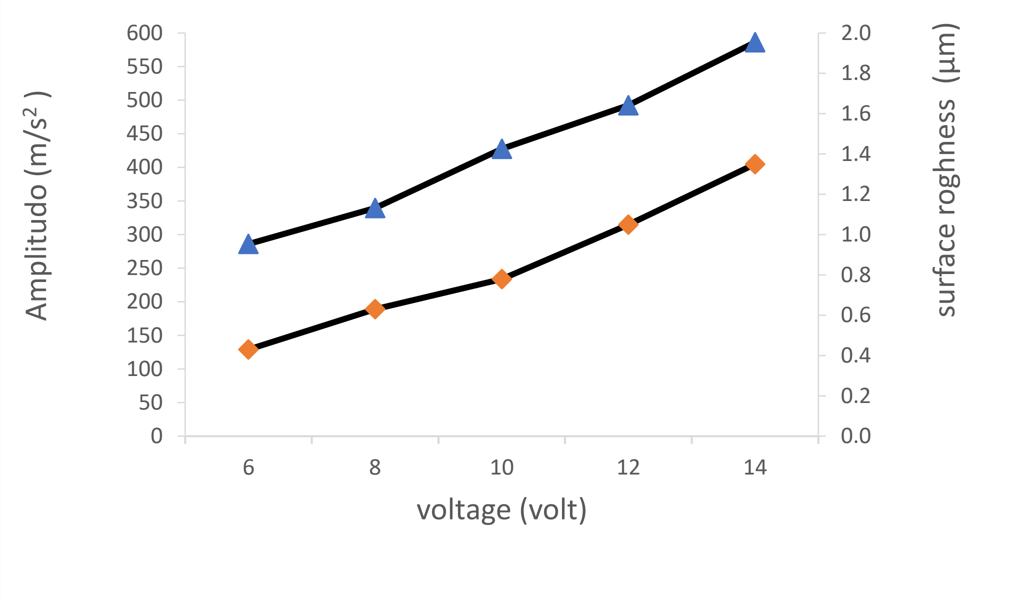


Figure 8 The relationship between amplitude, voltage, and surface roughness at peak amplitude on the x-axis for a current of 4 A

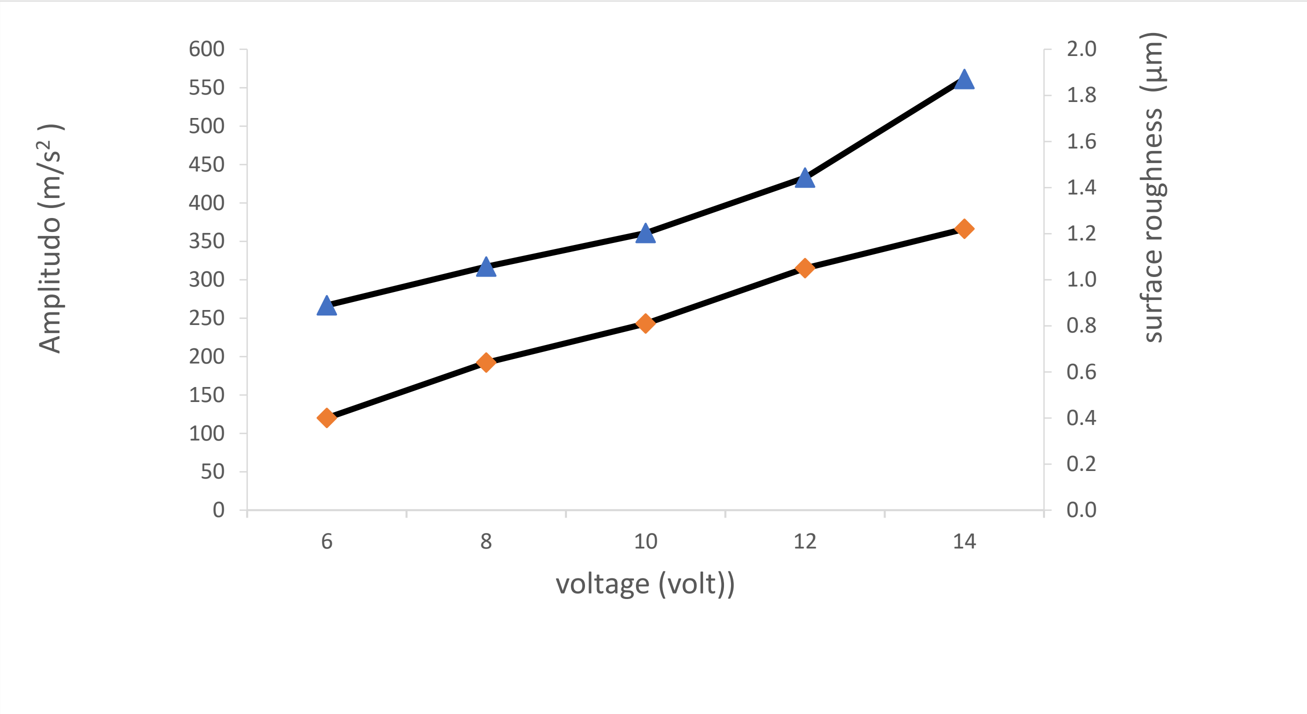


Figure 9 The relationship between amplitude, voltage, and surface roughness at peak amplitude on the *z*-axis for a current of 4 A

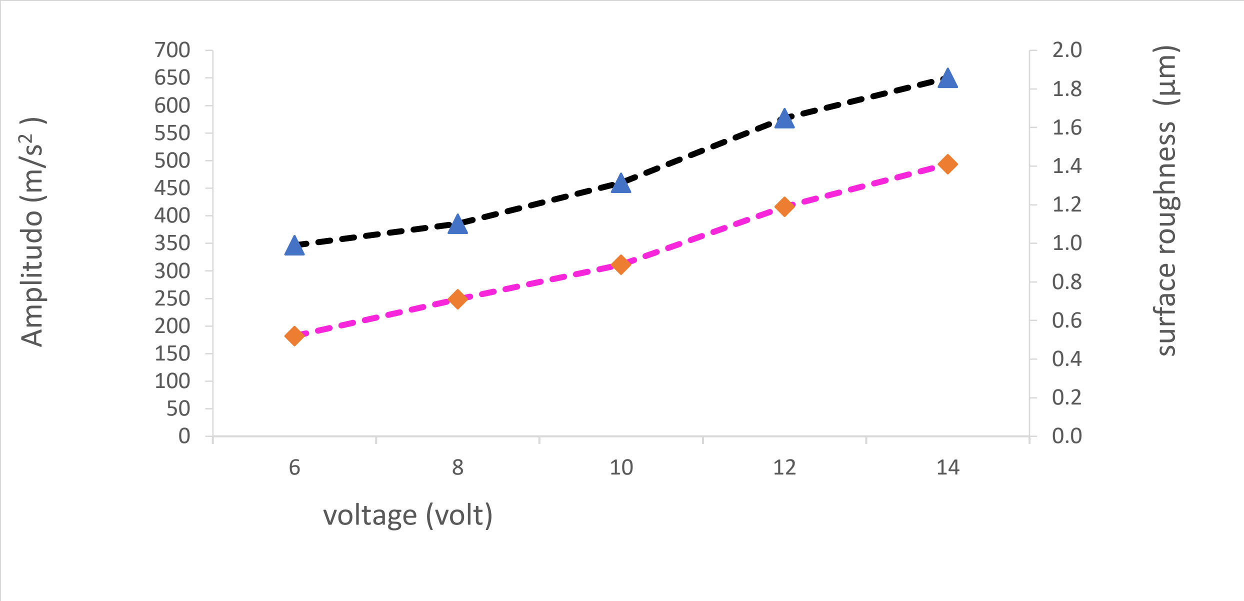


Figure 10 The relationship between amplitude, voltage, and surface roughness at peak amplitude on the x-axis for a current of 6 A

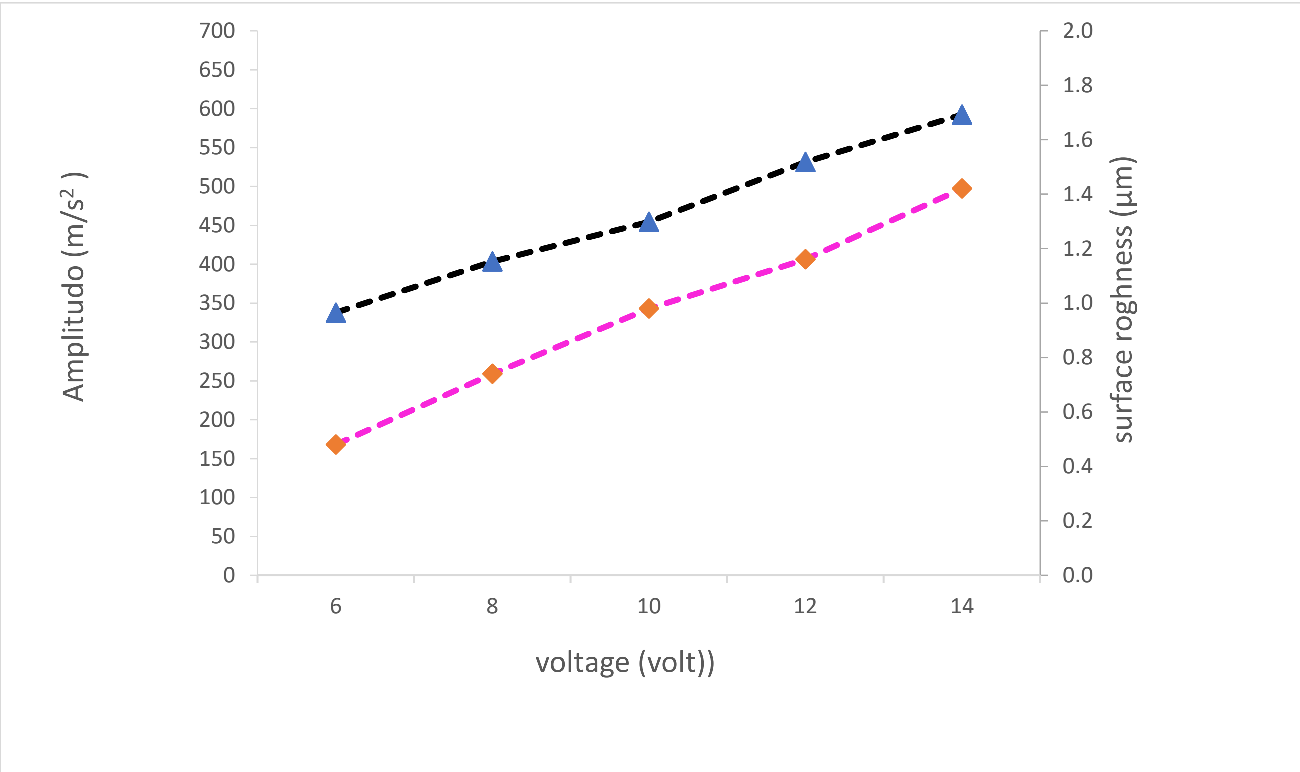


Figure 11 The relationship between amplitude, voltage, and surface roughness at peak amplitude on the z-axis for a current of 6 A

CONCLUSION

The difference in the magnitude of the strong current and voltage has a greater influence on the amplitude and surface roughness. The magnitude of the smallest vibration amplitude in a 6-volt block is 183.717 m/s^2 and the largest amplitude in a 14-volt load is 650.0344 m/s^2. The greater the voltage and electric current, the greater the amplitude and surface roughness produced so that the vibration is also greater.

ACKNOWLEDGEMENT
We are grateful to Eli Novita Sari Author 1, Chairul Anam Author 2, and Mahros Darsin Writer 3 for their contributions to this work. Special thanks to the Banyuwangi State Polytechnic for their assistance and the Funding Institution/Grant Number 3803/PL36/AL/04/2024 for financial support.

Funding Statement

This research is supported by the Banyuwangi State Polytechnic under Grant Number 3803/PL36/AL/04/2024.

REFERENCES
1. K. H. Ho, S. T. Newman, S. Rahimifard and R. D. Allen, State of the Art in Wire Electrical Discharge Machining (WEDM), vol 44, Issues 12-13, pp 1247-1259, 2004.
2. S. Kalpakjian and S. R Schmid, Manufacturing Process for Engineering Materials, Pearson Education, South Asia, 2009.
3. H. T. Lee and T. Y. Tay, Relationship between EDM Parameters and Surface Crack Formation, Journal of Materials Processing Technology, vol 142, no. 3, pp 676-683, 2003.
4. T. R. Newton, S. N. Melkote, T.R. Watkins, R. M. Trejo, and L. Reister, Investigation of the Effect Process Parameter on Formation and Characteristic of Recast Layer in Wire-EDM of Inconel 718, Journal of Materials Science and Engineering, vol 513, pp 203-215, 2008.
   A. Kumar, V. Kumar, and J. Kumar, Experimental Investigation on Material Transfer Mechanism in WEDM of Pure Titanium (Grade-2), Advances in Materials Science and Engineering, 2013.
5. EROL, S. S., "A Research Study on Vibrating Elements and Consuming Electricity in Predictive Maintenance", European Journal of Interdisciplinary Studies. 2(3), 45-50, 2016.
6. LAISSAOUI, A., BOUZOUANE, B., MILOUDI, A., HAMZAOUI, N., "Perceptive analysis of bearing defects (Contribution to vibration monitoring)", Applied Acoustics. 140,248-255, 2018.
7. Pawar P, Kumar A, Ballav R. Development and manufacturing of arduino based electrochemical discharge machine. *J Mach Eng* 2018; 18: 45–60.
8. Sibalija T V. Particle swarm optimisation in designing parameters of manufacturing processes: A review (2008–2018). *Appl Soft Comput J* 2019; 84: 105743.
9. Rao RV, Kalyankar VD. Optimization of modern machining processes using advanced optimization techniques: A review. *Int J Adv Manuf Technol* 2014; 73: 1159–1188.
10. Teixidor D, Ferrer I, Ciurana J, et al. Optimization of process parameters for pulsed laser milling of micro-channels on AISI H13 tool steel. *Robot Comput Integr Manuf* 2013; 29: 209–218.
11. EDE, K. N., OGBONNAYA, E. A., LILLY, M. T., "Vibration Monitoring of Rotating Systems", Engineering. 2(1), 46-54, 2010.
12. CASTILLA, J., FORTES, J.C., DÁVILA, J.M., MELGAR, S., SARMIENTO, A., "Predictive maintenance of mining machinery based on vibrational analysis" In: Proceeding of 18th International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management (SGEM), pp. 663-668, Bulgaria, July. 2018.
13. DIVEKAR, P. MANUGADE, P. KAMBLE, A. HARAGAPURE, A.A., "Vibration Measurement Us-ing Accelerometer and Arduino" International Journal of Recent Innovation in Engineering and Re-search. 2(3) : 177-179, 2017.
14. LEE, C.Y., SU, HUANG, T. S., LIU, M. K., LAN, C. Y., "Data Science for Vibration Heteroscedasticity and Predictive Maintenance of Rotary Bearings", Energies. 12(5), 801-818, 2019.
15. S. S. Mahapatra and A Patnaik, Optimization of Wire Electrical Discharge Machining (WEDM) Process Parameters Using Taguchi Method, vol 34, Issues 9-10, pp 911-925, 2007.
16. Li JG, Yao YX, Gao D, et al. Cutting parameters optimization by using particle swarm optimization (PSO). In: *Applied Mechanics and Materials*. Trans Tech Publ, 2008, pp. 879–883.
17. Uddeholm, EDM of Tool Steel, Edition 3, Austria, 2007
18. M. A. Hassan, N. S. Mehat, S. Sharif, R. Daud, S. H. Tohadi, and M. S. Reza, Study of the Surface Integrity of AISI 4140 Steel in Wire Electrical Discharge Machining, Proceeding of the International MultiConference of Engineers and Computer Scientists, vol II, 2009.