THE EFFECT OF THE PULSE CURRENT IN WIRE ELECTRIC DISCHARGE MACHINE ON MEASUREMENT ERROR TOWARD ALUMINUM ALLOY: AN EXPERIMENTAL STUDY

Amrullah*, Rahman Hakim*

1Politeknik Negeri Ujung Pandang
Mechanical Engineering Study Program
Jl. Perintis Kemerdekaan KM.10 Makassar, Indonesia
*E-mail: amrullah@poliupg.ac.id

2Politeknik Negeri Batam
Mechanical Engineering Study Program
Parkway Street, Batam Centre, Batam 29461, Indonesia
#E-mail: hakim@polibatam.ac.id

Abstract
This research investigates the measurement error on Wire EDM cutting products to find the pulse current's problem-solving. One of the machining parameters that affect the precision of Wire EDM is the magnitude of the current. The experimental study carried out by using the pulse current started from 4-Ampere up to 8-Ampere as the research parameters. A chamfer dimension on 6061 Aluminum alloy was investigated with the gd&t method with ISO 5459 and ISO 1101 standard. Statistic method applied and processed on Minitab with Shapiro-Wilk parameter for normal distribution. These experimental studies have a normal distribution that finds the phenomena of 8-Ampere of pulse current generate a large measurement error. Furthermore, in these experimental studies, the usage of a Profile Projector generates a massive measurement error, up to 64.5% compared with CMM. A strong commitment to calibrate the Profile Projector up to date to maintain the machining quality.

Keywords: WEDM, Pulse Current, Aluminum 6061 Alloy, GD&T.

1. Introduction
Wire Electric Discharge Machine (WEDM) is a non-conventional cutting machine. Using wire supplied with an electric current in, it can do the cutting process with various metal types. This machine usually uses to obtain high precision and highly complicated products [1].

Wire Electric Discharge Machines have different parameters in terms of pulse current, feed rate, and pulse frequency. The Parameters that are influencing the dimensional results are current or pulse current [2]. The more significant of the current flowing, the dimensional precision of a product decreases. It must choose the right type of current and pay attention to the type of material used [3].

This study explained the effects of various kinds of electric currents on the dimensions of an aluminum part and determining the right parameters in working on the product on the Wire Electric Discharge Machine. Furthermore, a comparison of each product’s dimensions has been processed with current magnitude 4-Ampere, 6-Ampere, and 8-Ampere. A heat generated by low pulse current with a diameter of 0.2 mm brass wire, with a 2 mm/min feed-rate on 6061 Aluminum Alloy produced the smooth cutting surface and minimum of MRR [4].

According to Geng, a corner-cutting system for an aluminum product with the radius corner-profile is used to vary the finished product’s shape. An optimizing method is applied to get the corner-angle cutting quality with the product [5]. Kandpal, investigate the surface quality of 6061 on SEM and
effect of pulse current variations on Wire Electric Discharge Machine (EDM) on the surface roughness and overcut. EDM is a subtractive machining process that uses discharge energy to remove material from a workpiece. In this study, the pulse current, wire diameter, and wire feed rate were varied to investigate their effects on the dimensional accuracy and surface roughness of the machined parts.

The EDM used in this study is a Sodick Wire Electric Discharge Machine (LN1W), with wire diameters of 0.2 mm. The wire electrode used is Brass with a diameter of 0.2 mm, with a 2 mm/min speed [4]. An Aluminum 6061 Alloy with 10mm thickness was used to investigate the corner shape, chamfer, and dimensional accuracy. The measurement error on the chamfer dimension represents the Wire EDM axis’s maintenance issues.

The measuring device with the touching method is CMM (Coordinate Measuring Machine), Mitutoyo Crysta-Plus M443. That metrology measuring machines can produce coordinates with ±3µm accuracy in three-dimensional structures with mutually perpendicular axes to each other [10]. Furthermore, TMS (Topography Measuring System) or well known as a Profile Projector, Nikon DP-303 Data Processor, used to be investigated by using the visual method. This visual measuring method can generate the dimension with ±25µm accuracy in a two-dimensional layout [11].

Figure 1. Detail Drawing of a 6061 Aluminum Part

The drawing prepared (Fig. 1) according to ISO 5459 standards and ISO 1101. ISO 5459 is geometrical tolerancing that describes the datum system [12]. ISO 1101 is Geometrical tolerancing describes tolerance of form and orientation [13]. The geometrical tolerance was applied to detail-drawing about 20µm.

The design of the experiment generated from two-level of measuring devices and three-level of pulse current parameters. The measurement data took eight times for a single form of the specimen.

2. Research Method

The Wire EDM used in this study is a Sodick Wire Electric Discharge Machine (LN1W), with wire diameters of 0.2 mm. The wire electrode used is Brass with a diameter of 0.2 mm, with a 2 mm/min speed [4].

An Aluminum 6061 Alloy with 10mm thickness used to investigate the corner shape, chamfer, dimension. The measurement error on the chamfer dimension represents the Wire EDM axis’s maintenance issues.

The measuring device with the touching method is CMM (Coordinate Measuring Machine), Mitutoyo Crysta-Plus M443. That metrology measuring machines can produce coordinates with ±3µm accuracy in three-dimensional structures with mutually perpendicular axes to each other [10]. Furthermore, TMS (Topography Measuring System) or well known as a Profile Projector, Nikon DP-303 Data Processor, used to be investigated by using the visual method. This visual measuring method can generate the dimension with ±25µm accuracy in a two-dimensional layout [11].

The Wire EDM used in this study is a Sodick Wire Electric Discharge Machine (LN1W), with wire diameters of 0.2 mm. The wire electrode used is Brass with a diameter of 0.2 mm, with a 2 mm/min speed [4].

An Aluminum 6061 Alloy with 10mm thickness used to investigate the corner shape, chamfer, dimension. The measurement error on the chamfer dimension represents the Wire EDM axis’s maintenance issues.

The measuring device with the touching method is CMM (Coordinate Measuring Machine), Mitutoyo Crysta-Plus M443. That metrology measuring machines can produce coordinates with ±3µm accuracy in three-dimensional structures with mutually perpendicular axes to each other [10]. Furthermore, TMS (Topography Measuring System) or well known as a Profile Projector, Nikon DP-303 Data Processor, used to be investigated by using the visual method. This visual measuring method can generate the dimension with ±25µm accuracy in a two-dimensional layout [11].

Figure 1. Detail Drawing of a 6061 Aluminum Part

The drawing prepared (Fig. 1) according to ISO 5459 standards and ISO 1101. ISO 5459 is geometrical tolerancing that describes the datum system [12]. ISO 1101 is Geometrical tolerancing describes tolerance of form and orientation [13]. The geometrical tolerance was applied to detail-drawing about 20µm.

The design of the experiment generated from two-level of measuring devices and three-level of pulse current parameters. The measurement data took eight times for a single form of the specimen.

3. Result and Discussion

The normality test carried out using the Shapiro-Wilk test found in the Minitab program. H₀ rejected if the p-value is smaller than α = 0.05.

Figure 2 shows that the data spread around the diagram and follows a regression model to conclude that the processed data normally distributed data so that the normality test.

Figure 2 (a) shows that the measurement results using CMM, then carried out the Shapiro-Wilk test, obtained P-Value larger than 0.1, which means higher than α = 0.05. Therefore, it can be concluded that H₀ is accepted.

Figure 2 (b) shows that the Profile Projector's measurement results then carried out the Shapiro-Wilk test and obtained a P-Value of 0.063, which means higher than α 0.05. Then, it can be concluded that H₀ is accepted.

Figure 3 shows that the data spread using the box plot. The measurement results on the pulse current parameter of 4 Amperes, using CMM, has a standard dev value of 0.0153-deg and a mean value of 44.956-deg. While the measurement results using Profile Projector have a value of std dev 0.0789-deg and a mean value of 44.830-deg. Using both CMM and Profile Projector measurement methods, the chamfer dimension is accepted, and the minimum dimension level is 44.800-deg.

The measurement results on the pulse current parameter of 6 Amperes, using CMM, have a standard dev value of 0.00725-deg and a mean value of 44.923-deg. While the measurement results using Profile Projector have a value of std dev 0.0298-deg and a mean value of 44.519-deg. Using CMM measurement methods, the chamfer dimension is
accepted, and the minimum dimension level is 44.800-deg. However, the chamfer dimension from Profile Projector measurement methods is rejected, and the result is lower than 44.800-deg.

![Figure 2. Normality test of (a) CMM data, (b) TMS data](image)

Furthermore, the measurement results on the pulse current parameter of 8 Amperes, using CMM, has a standard dev value of 0.00394-deg and a mean value of 44.878-deg. While the measurement results using Profile Projector have a value of std dev 0.0167-deg and a mean value of 44.233-deg. Using CMM measurement methods, the chamfer dimension is accepted, and the minimum dimension level is 44.800-deg. However, the chamfer dimension from Profile Projector measurement methods is rejected, and the result is lower than 44.800-deg.

![Figure 3. Box plot data of CMM data and TMS data](image)

The difference in measurement results between CMM and Profile Projector at 4 Ampere variable pulse current is 12.6%. For a pulse current of 6 Amperes, the difference in measurement results is 40.4%. Whereas for a pulse current of 8 Amperes, the difference in measurement results is 64.5%. It happens as an outcome, the pulse current value increases. The heat source then produced a high value of MRR, and it has rough surface quality [6].

Afterward, ISO 5459 and ISO 1101 standards ultimately passed. Consequently, the center's angularity with the corner edge reached the minimum level of the chamfer dimension 0.020-deg while using CMM. On the other hand, Profile Projector has a large measurement error and increases the pulse current. It arises as an outcome of Profile Projector using a visual method that has less accuracy than the touching method by the CMM probe. Simultaneously, measure a rough surface due to a large pulse current—furthermore, the last calibration of Profile Projector since 2016.

The pulse current effect based on the CMM and Profile Projector data shows there is no correlation between the measurement data and the WEDM axis. As an outcome of those three-pulse current setting parameters, it has been accepted on the CMM method. On top of that, the maintenance activity should be done along their timeline period; it can preserve the WEDM machining quality.

4. Conclusions

The measurement result on 4 Ampere of pulse current has the best result of the machining process that generates a 44.956-deg as mean value with CMM. It has a 12.6% measurement error with Profile Projector. For the next plan, the Profile Projector should re-calibrate to meet the industrial requirement.

Acknowledgment

The authors gratefully acknowledge the contributions of Politeknik Negeri Batam and the Machinery Department on PT. Indina Industri Indonesia Under an agreement on a Year Internship Program.

References

[1] A. Pramanik, A. K. Basak, M. N. Islam, and G.
Littlefair, “Electrical discharge machining of 6061 aluminium alloy,” *Trans. Nonferrous Met. Soc. China (English Ed.)*, vol. 25, no. 9, pp. 2866–2874, 2015.

[2] D. Pramanik, A. S. Kuar, and D. Bose, *Renewable Energy and its Innovative Technologies*. Springer Singapore, 2019.

[3] T. H. Ningsih, B. O. Soepangkat, and B. Pramujati, “Pengaruh Variabel Pemesinan Edm Wire Cutting Dengan Pemakaian Wire Berulang Terhadap LaJu Pengerjaan Material Benda Kerja, Kekasaran Permukaan Dan Ketelitian Ukuran Hasil Pengerjaan,” in *Seminar Nasional Teknik Mesin*, 2011, pp. 2–3.

[4] Sanchez, J. A., J. L. Rodil, A. Herrero, L. L. De Lacalle, and A. Lamikiz, “On the influence of cutting speed limitation on the accuracy of wire-EDM corner-cutting,” *J. Mater. Process. Technol.*, vol. 182, no. (1-3), pp. 574–579, 2007.

[5] G.H. *Manufacturing Engineering Handbook*. California: Mc Graw Hill Companies, 2004.

[6] B. C. Kandpal, J. Kumar, and H. Singh, “Optimization and characterization of EDM of AA 6061/10%Al2O3 AMMC using Taguchi’s approach and utility concept,” *Prod. Manuf. Res.*, vol. 5, no. 1, pp. 351–370, 2017.

[7] A. D. Wilujeng and R. Hakim, “Rancang Bangun Purwa-Rupa Cmm Tower Fixture Sebagai Dasar Media Pembelajaran Gd&T,” *Rotasi*, vol. 22, no. 1, pp. 43–47, 2020.

[8] B. H. Irawan, R. Hakim, H. Widiastuti, D. Kamsyah, and B. Sahputra, “Pengaruh Temperatur Nozzle Dan Base Plate Pada Mesin Leapfrog Creatr 3D Printer Terhadap Density Dan Surface,” *J. Teknol. dan Ris. Terap.*, vol. 1, no. 1, pp. 32–37, 2019.

[9] Saeedullah, M. and S. W. Husain, “Comparison of Geometric Design of a Brand of Stainless Steel K-Files: An In Vitro Study,” *J. Coll. Physicians Surg. JCPSP*, vol. 28, no. 4, pp. 327–329, 2018.

[10] H. D. S. Budiono and F. Hartanto, “PERANCANGAN DAN PEMBUATAN PROTOTIPE JIG UNTUK PROSES PEMBUATAN SEPEDA LIPAT STUDENT VERSION,” in *Seminar Nasional Tahunan Teknik Mesin (SNTTM) ke-9*, 2010, pp. 13–15.

[11] A. Pantira, T. Masuda, H. Takahashi, and H. Miura, “Gingival sulcus simulation model for evaluating the penetration characteristics of elastomeric impression materials,” in *International Journal of Prosthodontics*, 2003.

[12] M. Petitcuenot, L. Pierre, and B. Anselmetti, “ISO specifications of complex surfaces: Application on aerodynamic profiles,” *Procedia CIRP*, vol. 27, pp. 16–22, 2015.

[13] Z. Humienny, “State of art in standardization in GPS area,” *CIRP J. Manuf. Sci. Technol.*, vol. 2, no. 1, pp. 1–7, 2009.