A Review on: Effect of controllable factor on Material removal rate and surface roughness during WEDM

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Abstract. Wire EDM is a variant of electric discharge machining process that is widely accepted contact less type machining process for hard material to generate convolute and complex contour. It uses energy generated because of electric discharge between a continuously moving wire and work piece resulting disintegration of material from parental material. Surface generated by process have great quality and precision. In this article author discussed current trend in field of wire cut electric discharge machining while discussing finding by latest published paper by journal of repute. Authors discussed science behind pattern of effect of various controllable factor on target or required quality characteristic that include rate of material being removed, surface roughness, width of kerf because of wire travelling etc. A brief of different factor on machining rate is discussed along with future possibilities in field of machining using WEDM.

Keywords: WEDM, Surface finish, Kerf width, MRR.

1. Introduction

WEDM is a variant of die electric discharge machining process where in thermo-evaporation process happens that machine workpiece material by a progression/series of discrete electrical sparks/series of sparks starts between the workpiece and terminal that is wire in case of WEDM [1]. It is among essential non-customary manufacturing method utilized for removal of material from hard-to-cut materials and particularly many-sided profiles/contours [2]. It is broadly utilized nonconventional machining process, or, in other words, assembling of complex 2D and 3D Shapes [3] with electrically conductive workpiece utilizing wire terminal by utilizing non-ordinary machining process [4]. WEDM is competent to machine good quality, temperature resistive material with no geometrical mistake [5]. It has numerous applications in aviation, atomic, car industry, tool and die industry [6]. In the traditional cutting creation of a perplexing shape in difficult to machine, work-pieces are a troublesome phenomenon. In this manner, advance nonconventional machining processes like WEDM [7] are adequately utilized as an elective process to beat this issue [8]. The machining execution of the electric discharge machine is characterized and impacted by its process parameters, which altogether influences creation [9] rate and the nature of the machined part. The manufacture of the exact workpieces requires numerous long periods of [10] manual crushing and cleaning without WEDM.

1.1 Overview of WEDM

In the WEDM process, analyze the diverse input and output parameters dependent on machining execution process is made. Here, the expulsion of material happens because of electric discharge generated by intermittent [26] direct flow control supply between the anodes and the system is of metal evacuation in wire electrical discharge machining [27]. In WEDM, one terminal is the workpiece and the other electrode is a moving wire. The spark is created between two terminals flooded by dielectric
fluid. Deionized Water is utilized as a dielectric in wire cut electric discharge, due to its suitable viscosity and fast cooling rate. Gap voltage keeps on facilitating ionizes the channel and an intense attractive field is created. This attractive field ensure motion of electron from each terminal lead to thermal evaporation of material. The high kinetic energy of ions leads to disintegrates a piece of material from both the wire and workpiece by locally liquefying and vaporizing and it is the overwhelming warm disintegration process. In this process the electrode is a metal wire that came from spool mounted and is guided by upper and lower wire guiding mechanism, and afterward disposed when it is utilized. We are having a numeric control system with help of which movement of wire is programmed using user interface of machine. Initially work-piece is flooded with or submerged in insulated liquid dielectric then a pulsating current is passed through wire/tool that creates a series of sparks between job and wire itself that too relying on parameters setting done through control system. Between the two metal parts, an electric pressure is made when the flow is exchanged on. The electrode and machine utilize the machined shape to disintegrate the reverse shape in the workpiece. This process is likewise extremely precise and Applicable to cut very hard and complexed shaped work-pieces like required in aerospace nuclear industries [27]. It utilizes metal, tungsten, or copper as its material for the terminal apparatus wire. Deionized water is utilized for the dielectric liquid. Almost like the standard EDM, the wire is disintegrated and gradually sustained. In spite of the fact that it is like standard EDM, higher flows and lower rest times make this process considerably quicker.

2. Literature Review.

Sneha, P., A et al 2018. [11] Authors carried out Multi-Optimization of input factors during wire cut EDM of a bio-compatible grade of Titanium alloy grade five. They have found that WEDM was much of the time utilized for producing complex profiles that are needed for mechanical industries applications. The primary point of this investigation is to find combination of pulse on time, peak current along with feed rate of wire that results in high rate of material removal low width of kerf and minimum roughness for machining biocompatible titanium grade. The investigation of the outcome shows that the machining parameters have a noteworthy impact on the reactions. This examination controls the MRR, kerf width and SR for the desired applications. Choudhuri, Bikash et al 2018.[12] studied surface morphology of material specially RCL re-cast layer thickness while machining using wire cut EDM. Findings of authors were The surface nature of WEDM is dictated by the development of the recast layer and its harshness profile. The process parameters have an extraordinary relationship between these attributes. To achieve an extraordinary information of the surface harshness and recast layers of a surface machined by WEDM on treated steel 316, the sources of input and output connection has been built utilizing Artificial Neural Network (ANN) demonstrate. The rough surfaces, craters, micro defects, thick recast layers and consideration of outside molecule on the recast surfaces were obviously seen in the high energy harsh cut mode. Conde, A et al 2018. [13] Group studied accuracy in wire electrical discharge machining and Artificial Neural Networks (ANN) as optimization technique & found WEDM was a progressed non-ordinary machining strategy usually utilized in the creation of exactness parts into particularly hard materials. An approach to anticipating the precision of parts delivered process by utilizing an hybrid neuron network was proposed. By consolidating the predictions of the created LRNN and that of Simulated Annealing (SA) enhancement strategy, input range of variable can be planned, so radial deviations because of wire distortions got limited. The outcomes demonstrated that the new proposition was exceptionally productive in those circumstances in which wire deformation was most noteworthy. Khatri, Bharat C et al 2018. [14] Authors worked on hybridization of wire cut edm by utilization of ultrasonic agitation while in machining, they suggested a new way approach for machining using confinement of dielectric coupled with ultrasonic agitator, that process resulted as per their work higher cutting speed by aproximetly 40% improved surface finish and lower kerf width during machining. Kumar, Anish et al 2014 [15] worked on surface topography of titanium pure grade and wire
wear rate for wire cut electric discharge machining process. Their investigation is essentially centered on the examination of the topography of the work surface and wire electrode surface. [31-36] Test results demonstrated that Ton, Toff & Ip altogether influenced the surface topography with the development of profound wide covering craters, pockmarks, debris, and micro-cracks and RCL.

3.1 Effect of Controllable factors on Material Removal Rate

In this section as we all are aware that one of the drawback of wedm is its low rate of material removal, so researcher around the globe attempted to have best setting of input parameters so that we can have better or improved rate of material removal. MRR is the amount for how much material is detached from a part in a specified period of time. Some of the widely used influential input parameters used in WEDM are time duration between two sparks known as pulse on(Ton) and pulse off time(Toff) is the time for which the current is permitted to flow per cycle. Material removal is specifically corresponding to the measure of energy connected amid this on-time. Energy flow is controlled by combination of current and duration for which pulse is on. Toff is notation used for pulse off time that is duration of time between the flashes. Kerf can be explained as measure of the material that is scraped amid machining. Kerf width can decide the dimensional accuracy of the completing part and the interior corner range of the product in WEDM tasks.

3.1.1 Analysis of MRR

![Figure 2](image)

Figure 2 explains WEDM examination based on Pulse on time Vs MRR. Pulse on Time varies from 105 to 129 i.e., increases and MRR increases. The figure depicts that MRR increases as time duration of pulse is raised or increased. So the pulse on time can be adjusted to get the desired MRR. This happens because as we increase pulse on time energy that is applied got increased and hence improved the yield of material removal.
Different authors give an explanation with the different MRR based on time. The above figure 3 depicts that the rate of material removal decreases with an increase in the pulse off time. Accordingly pulse off time can be chosen in such a way that we get the preferred MRR. With respect to time, the MRR increases and then decreases.

3.2 Effect of Controllable Factors on Surface Finish

One of the best thing about non-traditional machining processes are their level of surface finish produced. Authors worked in this field continuously strives for improvement in material removal rate while maintaining an acceptable range of surface roughness. As the pulse duration of spark increase energy input material removed abruptly hence increase in roughness. As rate of removal of material increases surface roughness increases. Apart from above input material wire feed rate vs surface roughness is shown in figure below. As wire feed rate increase new wire came and improvement in finish occurs that means roughness decreases. Here different authors described different SR value based on increasing wire feed rate. The wire feed rate increases and correspondingly the SR value decreases.
Figure 5 demonstrates error analysis based on different techniques. Different techniques ANOVA, Taguchi method, ANN and SEM are analyzed for this research and finding the results.

4. Conclusion

This paper exhibited a survey of WEDM with the removal of undesirable material with the machining process and used to fabricate complicated shapes with incredible precision and great surface harshness. Turning with WEDM is the developing non-c customary machining processes to produce investigation. Almost 15-35 research papers are dissected identified with a thermal examination of turning with WEDM, and its qualities. The existing literature doesn’t give sufficient outcomes to foresee the parameters dependent on WEDM. For accomplishing better outcome as far as hardness, mean Signal-to-Noise proportion and compute accuracy, in this manner we need to lead onward some sophisticated improvement procedures.

References

[1] Azhari, Azmir, Zanruzir Hamedon, and Mebrahitom Asmelash Gebremariam. "A study on Wire Breakage in Electrical Discharge Machining of Polyurethane Foam." Materials Today: Proceedings 4, no. 4 (2017): 5222-5227
[2] Chaubey, Sujeeet Kumar, and Neelkesh Kumar Jain. "Investigations on the surface quality of WEDM-manufactured meso bevel and helical gears." Materials and Manufacturing Processes 33, no. 14 (2018): 1568-1577
[3] Choudhuri, Bikash, Ruma Sen, Subrata Kumar Ghosh, and S. C. Saha. "Study of surface integrity and recast surface machined by Wire electrical discharge machining." Materials Today: Proceedings 5, no. 2 (2018): 7515-7524.
[4] Conde, A., A. Arriandiaga, J. A. Sanchez, E. Portillo, S. Plaza, and I. Cabanes. "High-accuracy wire electrical discharge machining using artificial neural networks and optimization techniques." Robotics and Computer-Integrated Manufacturing 49 (2018): 24-38.
[5] Gaikwad, Vaibhav, and Vijay Kumar S. Jatti. "Optimization of material removal rate during electrical discharge machining of cryo-treated NiTi alloys using Taguchi’s method." Journal of King Saud University-Engineering Sciences (2016).
[6] Gaitonde, V. N., M. Manjaiha, S. Maradi, S. R. Karkik, P. M. Petkar, and J. Paulo Davim. "Multiresponse optimization in wire electric discharge machining (WEDM) of HCHCr steel by integrating response surface methodology (RSM) with differential evolution (DE)." In Computational Methods and Production Engineering, pp. 199-221. 2017
[7] Giridharan, Abimannan, and G. L. Samuel. "Modeling and analysis of crater formation during wire electrical discharge turning (WEDT) process." The International Journal of Advanced Manufacturing Technology 77, no. 5-8 (2015): 1229-1247.

[8] Gupta, Kapil, and Neelesh Kumar Jain. "Analysis and optimization of micro-geometry of miniature spur gears manufactured by wire electric discharge machining." Precision Engineering 38, no. 4 (2014): 728-737.

[9] Goyal, Ashish. "Investigation of material removal rate and surface roughness during wire electrical discharge machining (WEDM) of Inconel 625 superalloy by cryogenic treated tool electrode." Journal of King Saud University-Science 29, no. 4 (2017): 528-535.

[10] Hotte, David, RomainSiragus, Y. Duroc, and S. Tedjini. "Directive and high-efficiency slotted waveguide antenna array for V-band made by wire electrical discharge machining." Electronics Letters 51, no. 5 (2015): 380-382.

[11] Khan, Noor Zaman, Zahid A. Khan, Arshad Noor Siddiquee, and Arindam K. Chanda. "Investigations on the effect of wire EDM process parameters on surface integrity of HSLA: A multi-performance characteristics optimization." Production & Manufacturing Research 2, no. 1 (2014): 501-518.

[12] Khatri, Bharat C., Pravin P. Rathod, Janak B. Valaki, and C. D. Sankhavara. "Insights into process innovation through ultrasonically agitated concentric flow dielectric streams for dry wire electric discharge machining." Materials and Manufacturing Processes 33, no. 13 (2018): 1438-1444.

[13] Kumar, Anish, Vinod Kumar, and Jatinder Kumar. "Microstructure analysis and material transformation of pure titanium and tool wear surface after wire electric discharge machining process." Machining Science and Technology 18, no. 1 (2014): 47-77.

[14] Manjaiah, M., S. Narendranath, S. Basavarajappa, and V. N. Gaitonde. "Wire electric discharge machining characteristics of titanium-nickel shape memory alloy." Transactions of Nonferrous Metals Society of China 24, no. 10 (2014): 3201-3209.

[15] Mohammadi, Aminollah, AlirezaFadaei Tehrani, Ehsan Emanian, and DavoudKarimi. "Statistical analysis of wire electrical discharge turning on material removal rate." Journal of materials processing Technology 205, no. 1-3 (2008): 283-289.

[16] Maher, Ibrahem, Ahmed AD Sarhan, Mohsen MaraniBarzani, and M. Hamdi. "Increasing the productivity of the wire-cut electrical discharge machine associated with sustainable production." Journal of Cleaner Production 108 (2015): 247-255.

[17] Nain, Somvir Singh, Dixit Garg, and Sanjeev Kumar. "Modeling and optimization of process variables of wire-cut electric discharge machining of superalloy Udiment-L605." Engineering Science and Technology, an International Journal 20, no. 1 (2017): 247-264.

[18] Pramanik, Alokesh, and A. K. Basak. "Degradation of wire electrode during electrical discharge machining of metal matrix composites." Wear 346 (2016): 124-131.

[19] Sneha, P., A. Mahamani, and Ismail Kakaravada. "Optimization of Wire Electric Discharge Machining Parameters in Machining of Ti-6Al-4Valloy." Materials Today: Proceedings 5, no. 2 (2018): 6722-6727.

[20] Sonawane, Sachin Ashok, and M. L. Kulkarni. "Optimization of machining parameters of WEDM for Nimonic-75 alloy using principal component analysis integrated with Taguchi method." Journal of King Saud University-Engineering Sciences (2018).

[21] Sudhakara, D., and G. Prasanthi. "Application of Taguchi method for determining optimum surface roughness in wire electric discharge machining of P/M cold worked tool steel (Vanadis-4E)." Procedia Engineering 97 (2014): 1565-1576.

[22] Sivanagamalleswara Rao, S., K. Venkata Rao, K. Hemachandra Reddy, and Ch VS Parameswara Rao. "Prediction and optimization of process parameters in wire-cut electric discharge machining for High-speed steel (HSS)." International Journal of Computers and Applications 39, no. 3 (2017): 140-147.

[23] Thankachan, Titus, K. Soorya Prakash, R. Malini, S. Ramu, PrabhuSundararaj,
Sivakumar Rajendran, Devaraj Rammasamy, and Sathiskumar Jothi. "Prediction of Surface roughness and Material removal rate in Wire Electrical Discharge Machining on Aluminum Based Alloys/Composites using Taguchi Coupled Grey Relational Analysis and Artificial Neural Networks." Applied Surface Science (2018).

[24] Ubale, Shahadev B., and Sudhir D. Deshmukh. "Experiment based parametric investigation and optimization of wire electrical discharge machining process on W-Cu metal matrix composite." Advances in Materials and Processing Technologies 4, no. 2 (2018): 210-226.

[25] V. Sharma, J. Prakash Misra, and P. Singhal, “Multi-Optimization of Process parameters for Inconel 718 while Die-Sink EDM Using Multi-Criterion Decision Making Methods,” J. Phys. Conf. Ser., vol. 1240, no. 1, 2019.

[26] V. Sharma, J. Prakash Misra, and P. Singhal, “Optimization of process parameters on Combustor Material Using Taguchi & MCDM Method in Electro-Discharge Machining (EDM),” Mater. Today Proc., vol. 18, pp. 2672–2678, 2019.

[27] Wan, Yanling, Lining Xu, Zhigang Liu, and Huadong Yu. "Fabrication of a super-amphiphobicaluminum alloy surface via wire electrical discharge machining and chemical etching technology." Micro & Nano Letters 12, no. 3 (2017): 175-178.

[28] Xu, Jinkai, Kui Xia, Zhongxu Lian, Linshuai Zhang, Huadong Yu, Zhanjiang Yu, Zhankun Weng, and Zuobin Wang. "Surface properties on magnesium alloy and corrosion behavior based high-speed wire electrical discharge machine power tubes." Micro & Nano Letters 11, no. 1 (2016): 15-19.

[29] Zhang, Zhen, Hao Huang, Wuyi Ming, Zhong Xu, Yu Huang, and Guojun Zhang. "Study on machining characteristics of WEDM with ultrasonic vibration and magnetic field assisted techniques." Journal of Materials Processing Technology 234 (2016): 342-352.

[30] Zhou, Chaolan, Xiaoyu Wu, Yanjun Lu, Wen Wu, Hang Zhao, and Liejun Li. "Fabrication of hydrophobic Ti3SiC2 surface with micro-grooved structures by wire electrical discharge machining." Ceramics International 44, no. 15 (2018): 18227-18234.

[31] N. K. Gupta, A. K. Tiwari, and S. K. Ghosh, "Experimental Study of Thermal Performance of Nanofluid-Filled and Nanoparticles-Coated Mesh Wick Heat Pipes," Journal of Heat Transfer, vol. 140, no. 10, 2018.

[32] P. K. Singh Rathore, S. K. Shukla, and N. K. Gupta, "Potential of microencapsulated PCM for energy savings in buildings: A critical review," Sustainable Cities and Society, vol. 53, p. 101884, 2020/02/01/ 2020.

[33] S. K. Verma, N. K. Gupta, and D. Rakshit, "A comprehensive analysis on advances in application of solar collectors considering design, process and working fluid parameters for solar to thermal conversion," Solar Energy, vol. 208, pp. 1114-1150, 2020/09/15/ 2020.

[34] A. Sharma, G. Bharadwaj, and Varun, "Heat transfer and friction factor correlation development for double-pass solar air heater having V-shaped ribs as roughness elements," Experimental Heat Transfer, vol. 30, no. 1, pp. 77-90, 2017/01/02/ 2017.

[35] K. Kumar, K. Sharma, S. Verma, and N. Upadhyay, "Experimental Investigation of Graphene-Paraffin Wax Nanocomposites for Thermal Energy Storage," Materials Today: Proceedings, vol. 18, pp. 5158-5163, 2019/01/01/ 2019.

[36] S. Pradeep Kumar and S. Kamal, "Mechanical and Viscoelastic Properties of In-situ Amine Functionalized Multiple Layer Grahene /epoxy Nanocomposites," Current Nanoscience, vol. 14, no. 3, pp. 252-262, 2018.