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Review on Parametric Optimization in Wire Electrical Discharge Machining

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A B S T R A C T

Wire cut electrical discharge machining (WEDM) is a new non-traditional manufacturing technology for cutting difficult-to-machine materials and complicated forms that are impossible to achieve with traditional machining processes. Wire cut EDM is also known as wire cutting and wire electrical discharge machining. A thin single-strand metal wire, generally brass, is passed through the work piece while immersed in a dielectric fluid, commonly de-ionized water. The most efficient use of the WEDM process necessitates careful selection of machining settings. WEDM is a complicated system that is governed by a huge number of variables.WEDM is a complicated system that is governed by a huge number of variables. Process parameters such as voltage, current, and pulse-related parameters (such as pulse on time and pulse off time) have been shown to be the most significant parameters in EDM/WEDM. They, together with interaction time (pulse width x frequency), are the most important output parameters, such as MRR, surface roughness, and so on. Pulse energy is responsible for the depth of the crater, the temperature created, and the resulting surfaces (together with their components). Various studies have concentrated on these factors and prescribed optimal energy delivery, therefore avoiding post-process problems.The effects of different WEDM process parameters like pulse on time, pulse off time, servo voltage, peak current, dielectric flow rate, wire speed, and wire tension on different process response parameters like material removal rate (MRR), surface roughness (Ra), Kerf (width of Cut), wire wear ratio (WWR), and surface integrity factors are discussed in this paper. This study also examines the researchers' optimization methodologies and concludes with recommendations and future trends in WEDM research.

Keywords:Process Parameters,Wire electrical discharge machining, Material Removal Rate (MRR), Surface Roughness (Ra). Process optimization,

1. Introduction

Wire-cut EDM has become a significant manufacturing method due to the advance of superior engineering materials and the requirement for complicated 3-dimensional molded components. Since the 1960 s, several attempts have been made to enhance the wire-EDM process's machining conditions, performance characteristics, and wire electrode qualities. Wire-EDM is a non-contact machining technology that has evolved from a simple production method for geometrically difficult or hard material parts and dies to a micro size application machining alternative that has attracted a lot of research attention. In recent years, wire-electrical discharge machining researchers have looked at a variety of techniques to increase sparking efficiency, including several novel experimental concepts that differ from the typical Wire-EDM sparking phenomena.

Nagaraja et al. (2015) conducted a research into parameter optimization in bronze-alumina MMC WEDM. The major goal was to determine the best cutting settings for achieving a low SR value. In this experiment, the input parameters were wire feed (WF), Ton, and Toff. Taguchi L9 orthogonal array was used to calculate cutting parameter values. The influence of the factors on SR was investigated using the signal to noise ratio and ANOVA. Each cutting parameter's contribution to the surface roughness is also determined. The WF was shown to be the most important feature impacting SR. When compared to a complete factorial design, the Taguchi approach is more appropriate for solving the given problem with a smaller number of trials

Rao and Venkaiah (2015) For plarming their tests while optimizing different PP on Nimonic-263 alloy, they used the CFCD of RSM. Input parameters included Toff, servo voltage, Ip, and Ton. The ANOVA approach is used to determine the importance of PP. They also created models for predicting MRR and SR values. Response Surface Methodology (SRM) MMR and SR optimum values were 3.59857 mm Vmin and 0.363163 |xm, respectively. Likewise, PSO determined that the best values for MMR and SR were 3.6713inmVmin and 0.261 Sum. The Particle Swarm Optimization technique was

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used to improve the findings. When the results of the Response Surface Methodology technique and the Particle Swarm Optimization algorithm were compared, the Particle Swarm Optimization algorithm outperformed the Response Surface Methodology approach.

Ramakrishnan and Karunamoorthy (2006) Tool electrodes are made of zinc-coated wire with a diameter of 0.25 mm. The pulse on time and the strength of the ignition current were shown to be the most important elements in influencing the varied reactions in the research.

Harshdeep and Ishu Monga (2015) used the design was utilised to optimise input parameters and output parameters. In addition, a multi-response technique was used to assess performance attributes that differed from the real value.

Kubade et al. (2015) used Taguchi L27 Orthogonal Arrays at three levels to optimise the process parametric combinations of wire speed, Toff, and Ton, wire speed on Titanium DibromideTiB2. For each experiment, for MRR, SR, and Overcut were determined.

Dewangan et al. (2015) used an EDM to process AISI P20 tool steel and looked at the influence of various input parameters on the material's surface integrity. SRM was used to design the studies. As input parameters, Ip, and Ton, were chosen. Grey Fuzzy Reasoning Grade was assessed using GRA and fuzzy logic. The major findings of their investigation were that the outcomes of surface integrity were primarily influenced by pulse on time followed by discharge current. Tw = 0.20 s, TUP = 0.00 s and IP - 1 A, TON = 10ms, were found to be the best values.

Rao et al. (2014) employed the Taguchi technique and Hybrid Genetic Algorithm when milling A aluminium 2014T6 alloy, with the use of LRM to improve SR and MRR. Ton, spark gap and Ip, all have an impact on SR and MRR. Finally, the thickness of the white coating on the specimens was measured, and the results were extremely high.

Saedon et al. (2014) In titanium alloy machining, the effects of Toff, wire tension, WF, and Ton, on RS, cutting rate, and MRR were studied. For multi-objective response variable optimization, a combined method of the orthogonal array and GRA was utilised. The best machining parameters were 12A Ip, 4 mm/min WF, 16 N wire tension, and 3ps pulse-off time.

Abinesh et al. 4 mm/min WF the goal was to explore and improve the potential process factors that influence MRR, SR, and Electrode Wear during Titanium alloy machining. The research looked at the relationship between several input process factors such as Toff, Ip, workpiece material, Ton and wire material.

Equbal et al. (2014) utilised the Taguchi technique with GRA to improve process parameters during spring saddle hot forging. L27 OA was used to investigate input factors such as billet temperature, friction coefficient, die temperature, and flash thickness, as well as their interactions. To find significant parameters, an analysis of variance is used. The most important criteria for forging load are flash thickness, billet temperature, and the relationship between the two. Finally, GRA was utilised to improve both CV and SR at the same time. CV and SR were shown to be significantly affected by Ip and Toff [22].

Rao et al. (2014) employed the Taguchi technique and Hybrid Genetic Algorithm when milling A aluminium 2014T6 alloy, with the use of LRM to improve SR and MRR. Ton, spark gap and Ip, all have an impact on SR and MRR. Finally, the thickness of the white coating on the specimens was measured, and the results were extremely high.

Goswami and Kumar (2014) employed in their study of Nimonic-80A, Taguchi's approach to construct the trials. SR, MRR, and WWR were all affected. When utilizing a stronger Ton setting, a thick recast layer was noticed. Also, when low values of Ton and large values of Toff were utilised as settings, lower values of wire deposition were found.

Shah et al. (2013) used Response Surface Methodology (RSM) to optimise WEDM operating parameters during inconel-600 machining. Four input parameters were chosen to investigate their influence on the performance answer of MRR in an experimental setting. The experiment was designed using Taguchi using a mixed LI 8 array, with ANOVA for analysis and RSM for developing surface models for response parameters. The influence of Toff, Ip, and Ton, has a substantial effect on MMR, according to ResuUs.

Sharma et al. (2013) The parameters were optimized using RSM, and they were designed using a central composite rotatable design. The relevant variables were determined using ANOVA. Experiments revealed that the length of time the pulse was on was the most important influence in cutting speed and dimensional variation.

Baig and Venkaiah (2014) used Taguchi and GRA to machine Hastelloy C276. The response variables were MRR and Kerf width. The most important element impacting the MRR and kerf width was shown to be the discharge current (Ip).

Sudhakara and Prasanthi (2014) Experiments were carried out on a Mitsubishi WEDM, and the Taguchi technique and ANOVA were used to determine the optimal variables. The influence of Ton followed by spark gap set voltage on SR was considerable. Material removal rate was virtually unaffected by wire input and Toff.

Nourbakhsh et al (2013) by the influence of seven process factors on the reactions when milling titanium alloy was studied. We compared the impacts of zinc-coated brass wire with high-speed brass wire. CV, wire breakage, and SR were all affected. The experiments were created using the Taguchi LI 8 design of experiment methodology. CV rises with Ip, pulse interval, and pulse width, according to observations. Uncoated wire also generates a surface finish with, meUed drips, craters, and more fractures according to SEM photos. To investigate the influence of various wires on workpiece material surface properties, scanning electron microscopic analysis of machined surfaces was done. Pulse interval and pulse width were the most influential parameters on the side of wire rupture.

Fard et al. (2013) by the tests were designed using L27 Taguchi's orthogonal array. To find important variables, an analysis of variances (ANOVA) was used. Al/SiC metal composite was employed as the workpiece material. The machining was carried out in a gaseous medium under dry dielectric conditions. An ANFIM was used to anticipate process features and correlate the connection between process inputs and responses. The impacts of the process variables of Toff, Ip, WF, gap voltage, wire tension, Ton, on cutting velocity and SR were determined. Following the use of ANFIM, the Artificial Bee Colony method was used to improve the cutting rate and SR parameters.

Kumar and Agarwal (2012) used a while machining high-speed steel, multi-objective GA to optimise the machining parameters for maximum MRR and lowest surface polish (M2, SKH9). MRR and SR were affected by WF, Toff, flushing pressure, Ton, wire tension, and Ip, as well as their interactions. As a tool, zinc coated copper wire was employed. Nonlinear regression analysis was used to build mathematical models between input parameters and responses. The results showed that pulse length, WF, Toff, and Ip, had a greater impact on MRR and surface polish than flushing pressure and wire tension. Ip=30 A, pulse duration=37 us, Toff=50 fis, WF =7.00 m/min, wire tension=1260g, flushing pressure=2.1 kg/cm were the optimum parametric combination with the greatest feasible MRR while keeping the stated surface polish criterion of 3.69 im.

Yang et al. (2012) while milling pure tungsten using a wire electrical discharge machining, attempted to investigate changes in MRR, RS, and comer deviation. Taguchi's parameter design technique, simulated annealing algorithm, back-propagation ANN, and response surface methodology, are all used in this study to offer an effective process parameter optimization strategy for wire electrical discharge machining processes. Furthermore, the field-emission SEM pictures revealed that the final surface following the wire electrical discharge machining procedure had a number of built-edge layers.

Shandilya et al. (2013) As input factors, Ton, WF, Toff, and servo voltage were chosen. The generated ANN models were associated to the response surface methodology mathematical models in terms of performance. The ANN model's prediction accuracy was almost three times that of the response surface methodology model. WF and pulse-off time were less important than voltage in determining average cutting speed. The prediction accuracy of the ANN model is greater than the response surface methodology model based on the correlation coefficient.

Shayan et al. (2013) used to design trials based on response surface technique, Central composite rotatable design. By using analysis of variances, experiential models were created to make connections between input components and their results.

Satish Kumar et al (2011) by the performance of WEDM parameters when machining A16063/SiCp composite was given. Four process parameters and two response parameters were chosen for this experiment. Because of this. Using the stir casting technique, Sic was combined as 5%, 10%, and 15% in Al, followed by machining of pure A16063 and Al-MMC. The experiment was designed using a L9 orthogonal array, and the results were analysed using ANOVA and a response graph. For MRR, the outcomes of various fractions were compared to unreinforced A16063. MRR was shown to decrease when SiC activities in MMC increased. With higher S fractions, SR rose as well.

Newton et al. (2009) attempted to identify the variables that influence the development of the recast layer in Inconel 718. When Ip, current pulse length, and the energy per spark, were raised, the average thickness of the recast layer rose. The average thickness of the re-cast layer was discovered to be between 5 and 9 |m. The development of the recast layer was unaffected by wire diameter or spark cycle duration.

Singh and Garg (2009) Using a one variable at a time strategy, studied the influence of different WEDM process parameters such as wire tension, Toff, Ip, WF, servo voltage and Ton, on hot die steel. It was expected that the best choice of process parameters would optimize the MRR. The Ip and Ton had a direct influence on MRR, but the Toff had an indirect impact. MRR was unaffected by WF or wire tension.

Mahapatra and Patnaik (2007) To design the experiment on various operational parameters, employed Taguchi's L27 OA and non-linear regression analysis. The workpiece material was D2 tool steel, and the response parameters were MRR, SR, and kerf width. Finally, in WEDM, a genetic algorithm was used to maximise multi-quality features. According to the findings, pulse duration, Ip, and the connection between pulse duration and Ip were the most critical parameters for cutting operations.

Jangra et al. (2011) While machining a combination of Cobalt and Tungsten Carbide, demonstrated the optimization of two quality characteristics: MRR and SR. Ip, wire tension, Ton, Taper angle, Toff, and dielectric flow rate were all employed in the research. Taguchi technique Grey Relational Grade was used to determine the best process parameter values. The most important parameters impacting the findings, according to ANOVA, were Ton and taper angle.

Muthu Kumar et al. (2010) employed when machining Incoloy-800 superalloy, the Grey-Taguchi technique to optimise various parameters. The experiment's results were visible on MRR, SR, and kerf.

Chiang and Chang (2006) studied the effects of various input parameters on SR and MRR when milling AiaOs particle reinforced material on a WEDM. The findings were optimised using Taguchi's LI 8 mixed OA and GRA design approach. The wire electrode used was 0.20mm in diameter and composed of pure copper. The arc arc off-time of discharging, servo voltage, on time of discharge, and on-time of discharging, all have a higher impact on cutting rate and SR, according to their findings.

Manna and Bhattacharyya (2006) The most important and significant machining factors that affect surface roughness are WF and wire tension. Similarly, the key factors for regulating spark gap were discovered to be spark gap voltage setting and wire tension. Mathematical models were created, as well as verification tests for the models that were created. The test results were evaluated to determine the best combination of parameters for successful Al/SiC-MMC machining. The study looked at the relative relevance of variables that affect certain machining qualities.

Tarng et al. (1995) For tackling the multi-response optimization issue, used a feed forward neural network system with a simulated annealing technique. The machining parameters of servo reference voltage, Ton, capacitance setting, Toff, no-load voltage, Ip, and servo speed setting have been discovered to be significant factors for estimating machining speed and SR.

Hewidy et al. (2005) used response surface approach to predict the WEDM process parameters while cutting Inconel 601. Ip seems to have a direct relationship with the rate of metal removal. MRR, on the other hand, shows a decrease after 7 A. MRR was raised until the duty factor reached 0.5[45].

Speeding and Wang (1995) the neural network was built using a feed-forward, backpropagation approach with a central composite rotatable experimental design. They used timeseries methods to better describe the WEDM produced surfaces.

Chen et al. (2013) The results reveal that the Ip and parameters are the most important factors in determining the amplitude of the SR. The ideal processing settings are used to manufacture a CuZn40 brass alloy specimen, which has a lesser mean SR than the A6061-T6 work-piece.

Guleryuz et al. (2013) looked into the impact of electric discharge machining settings on the SR while milling Al/SiCp metal matrix composites made using Powder Metallurgy. The process parameters were V, electrode type, particle reinforcement weight ratio, Ton, and Ip. Using the Taguchi orthogonal design, an experimental plan L18 was created. The most influential factors were Ton (34%) and Ip (31.26%), according to the findings. Aside from that, particle reinforcement accounts for 6.71 percent of the SR's contribution.

Lajis et al. (2009) Using Taguchi technique, investigated the possibility of machining WC ceramics by EDM using a graphite electrode. To construct the experimental layout, the Taguchi technique was used to analyse the influence of each parameter, such as V, interval time, pulse length, and Ip, on the machining characteristics, material removal rate and SR, and to forecast the best option. These factors are discovered to have a substantial impact on machining characteristics. The Taguchi technique indicates that the Ip has a considerable impact on the MRR and SR, whereas the pulse length has the most impact on the MRR.

Kansal et al. (2007) investigated the result of adding Si powder into kerosene as the EDM's DF on the machining properties of AISID2 die steel. Six process factors were considered: Toff, nozzle flushing, Ton, and Ip, powder concentration, and gain. The machining rate (MR) is used to gauge the efficiency of the process. Except for nozzle flushing, all of the specified factors had a substantial influence on the mean and variance in MR, according to this study. Using the Taguchi technique, optimization to maximise MR has also been attempted. According to the ANOVA, Ip and powder concentration had the greatest percentage contribution to MR of all the factors.

Manikandan and Venkatesan (2012) the geometry of the machined micro-holes, as well as the resolicited material surrounding the hole opening, are studied. To further comprehend this study, several detailed photos taken using a scanning electron microscope (SEM) are given.

Huertas Talon et al. (2010) This application makes it easier to solve the equations that the mathematical model generates in order to determine the wire routing. The electro-erosion parameters for this alloy, namely amperage, pause, V, and power, were evaluated using an ONA PRIMA S-250. To achieve the best values for cutting Ti alloy, the Taguchi OA technique was selected. The WEDM technique employed here is a noteworthy alternative to traditional machine tools for cutting electrically conductible materials that are challenging to work with (milling, turning or boring).

Lin et al. (2006) The Taguchi technique was used to conduct the tests using the L18 OA. The machining features have a considerable impact on the important parameters no load voltage, p, Ip, auxiliary current, pulse length, and Servo reference voltage. With the increase in Ip, MRR and SR rose as well. The MRR and likewise the SR rose and subsequently decreased as the pulse length increased. At a given Ip, the TWR decreased as the pulse length grew.

Experiments were prepared and carried out by Amitesh Goswami et al [2] to evaluate the impact of cutting settings on MRR and SR in the WEDM process. This research shows that Nimonic-80A can be machined pretty well utilizing the Wire-EDM process. Single response optimization and multi response optimization approaches were used to produce optimized process conditions for two responses.

Brajesh Kumar Lodhia et al[54] used Taguchi's parametric design technique to process. Using AISI D3 steel, the influence of various machining parameters such as Toff, WF, Ip, and Ton was investigated. The Ton and current were shown to have a greater impact than the other factors studied in this study. The proof-of-concept experiment has been completed. The mistakes connected with SR are just 3.042%, according to the results. A.K. Roy,

Vikas, Shashikant, and Kaushik Kumar The determination of this study is to comparation the MRR of EN-19 materials and EN-41 materials in a die sinking Electrical discharge machining machine. The input processing parameters were Ton, Toff, Ip, and voltage, while the MRR was regarded the output. To forecast the optimal combination of inputs for greatest output, the Taguchi technique was used to optimize. In the case of EN41 and EN19 materials, it was discovered that the Ip had a greater influence on the MRR than other processing factors. A comparative analysis of the carbon makeup of both materials was also carried out. Aparna devi and colleagues The EN24 steel grade has a greater hardness than the EN8 steel grade. It's thought to be related to EN24's greater carbon and Cr content than EN8. Heat treatment has a significant impact on the mechanical and corrosion properties of specified steel grades, such as EN8 and EN24. The homogeneous distribution of carbides in the EN 24 grade of steel has resulted in superior corrosion resistance than the EN 8 grade of steel. Steels that have undergone annealing heat treatment have superior pitting corrosion resistance than steels that have undergone other heat treatments, which is due to the finer grains obtained during the annealing process. The goal of this research is to discuss how to utilise the Analytical hierarchy process approach to determine the best value for wire-cut EDM process output parameters. The orthogonal array of tag chi is used in this work for testing. Experiments are also carried out on EN31 alloy steel using 0.25mm diameter Brass wire. The findings achieved utilizing the AHP with MOORA approaches in this study are good, demonstrating the usefulness and potentiality of these approaches. T. Balusamy and colleagues The impact of SMAT on EN-8 steel pack boronization is investigated. Plastic deformation was generated by SMAT, which facilitated nano crystallization at the surface, increased the volume fraction of nonequilibrium gain borders and reduced grain size, and caused defects and inside grains and dislocations to accumulate at grain borders. These characteristics aided in the spreading of boron.

2. 2.2 LITERATURE CONCLUSIONS

The literature on wire-cut electrical discharge machining is categorised into distinct models based on the authors' approaches and solution approach. Figure 5 is a pie chart depicting the percentage distribution of wire-cut electrical discharge machining literature analysed. It is shown that empirical models are used in 26 percent of the research, whereas distinct optimization models are used in 21 percent of the research. Only twelve percent of the papers reviewed used artificial intelligence models to improve WEDM process performance. It was discovered that 22 percent of the literature examined uses a technical change to the fundamental WEDM procedure. In terms of numerical and analytical models, the graph demonstrates that only seven percent and fourteen percent of work in the WEDM process, respectively. Only 2 percent of study effort in the wire electrical discharge machining taper cutting process has used logical models, 1 percent of research work has used mathematical models, and 1 percent of research work has used mathematical models, according to the literature for WEDM straight cutting and taper cutting. As a result of identifying the gap in the literature, the proposed study plan was born[56].

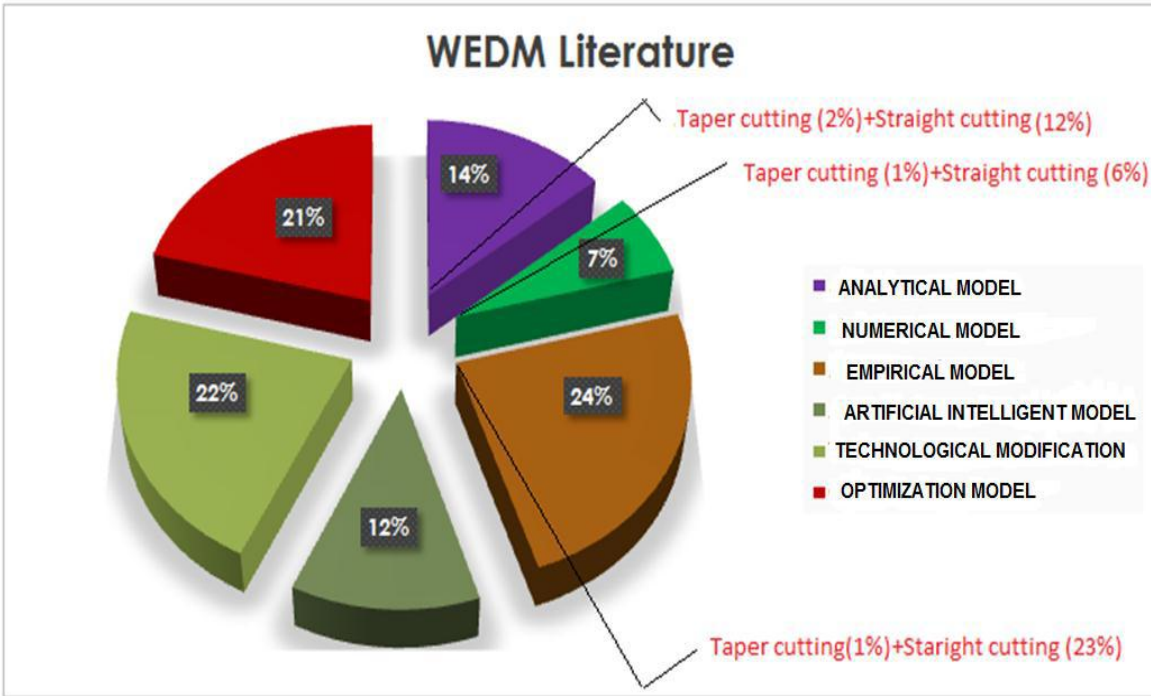

Figure1 : Literature evaluation in terms of percentage(Nayak, 2015)

3. CONCLUSION

Wire electrical discharge machining is a type of electrical discharge machining that uses wires. A moving wire along its axis, which generally unwinds from one storage roller and is coiled on another roller, was used in WEDM to reduce the impact of tool electrode wear. The advent and development of numerical control subsystems has aided the spread of the WEDM process substantially. Currently, there is an explosion of study on the WEDM process, which is being tackled from many angles. A quick statistical study revealed the scientific inquiry, implementation, and optimization of the WEDM method to be of significant interest.As a result, some research has been conducted to improve the WEDM system's different components. It has been noted that WEDM procedures are becoming more diverse. The attempt to adapt the WEDM method to a variety of materials, including the machining of workpieces composed of materials with extremely low electrical conductivity, was developed. Identifying and describing how input variables function in the WEDM process has been the subject of a variety of studies. The productivity of the process, the roughness and accuracy of the machined surfaces, the thickness of the heat-affected zone, the wear of the tool electrode, and the kerf width were all considered as output characteristics.Following a better understanding of the effect of process input variables on the values of output parameters, efforts to improve the WEDM process were made. Multicriteria optimization approaches were utilised more frequently than optimization methods. Mathematical models were built utilising contemporary mathematical techniques in both the investigation of the effect of input elements on the values of output parameters and the study to improve the WEDM process.The literature review found that the number of works published in recent years has increased significantly, and it covers difficulties connected to the WEDM process. In the coming years, this tendency is anticipated to continue. The focus in the future is expected to be on studying the possibility of employing new versions of the WEDM process, as well as applying this method in the machining of yet-to-be-identified materials. There will be further efforts to optimise WEDM processes, including new needs particular to the industry 4.0 stage.

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