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A Review on: Wire cut electrical discharge machining process for power tool manufacturing

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Abstract

It is a non-conventional material removal technology that uses a quickly recurring sparks technique between the non-contact electrode and the workpiece to successfully machine hard-to-cut materials in complicated shapes and geometries with high precision and good surface roughness. Numerous WEDM-related studies and research have found that good process, material, and operating parameter selection has enhanced process characteristics such as material removal rate, surface quality, and tool wear rate, among others. The optimum approach must be employed for appropriate selection of the process, material, and operating parameters, according to studies related with the WEDM. This article examines the machining of power tool manufacture steel, as well as the Material Removal Rate, Surface Quality, and Evaluation Models and Techniques.

Keywords: WEDM, power tool manufacturing steel, Process parameters, Optimization processes.

1. Introduction

Wire EDM has grown in importance as a non-conventional machining method in aerospace engineering, tooling, dies, moulds, metalworking, and the automotive sectors. This is since wire EDM is a cost-effective way to machine hard materials with complex forms. However, the problem of determining cutting parameters to achieve a greater cutting rate or accuracy in wire EDM is still unsolved. The WEDM process is a thermal method of removing material from a work piece using a sequence of sparks between the wire electrode and the work piece. The WEDM technique has shown to be a competitive and cost-effective machining alternative for demanding machining requirements ranging from simple tooling to sophisticated die building processes during the last decade. WEDM is now widely utilized for machining materials ranging from traditional materials to advanced materials. Table 1 shows different types of steels composition, properties, and applications of the same.

WEDM (wire electrical discharge machining) is a type of non-contact thermal machining technology. The WEDM technique has shown to be a competitive and cost-effective machining alternative for demanding machining requirements ranging from simple tooling to sophisticated die building processes during the last decade. WEDM is now widely used for machining materials ranging from common materials to special materials such as alloy steel, tool and die steel, and high strength steel, all of which have numerous applications in the automotive, aircraft, and railway industries, as well as defense, aerospace, and micro systems industries. WEDM (Wire Electrical Discharge Machining) has a better capacity to cut complicated forms with great precision in difficult-to-cut steel. Because of its higher hardness and strength, conventional machining of special steel produces severe tool wear. As a result, action is required.

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Table 1: Different types of steels composition, properties.

Sr. No.	Types of Steel	Composition	Properties	Applications
AISI 4140 steel	chromium-molybdenum alloy high tensile steel	DIN 42CrMo4	high strength and hardenability, good toughness, small deformation during quenching, high creep strength and long-lasting strength at high temperature.	aerospace, oil and gas and automotive industries thin-walled pressure vessels, forged gears and
SKD11 alloy steel	high carbon and high chromium cold-work alloy tool steels	Cr12Mo1V1	high hardness, strength, and wear resistance	cold work or hot work dressing dies, sides of rollers, screw lines, lines dies, transformer core stamping dies,
AISI D5 tool steel	High-Carbon, High-Chromium, Cold-Work Steels	Cr12MoV	high wear resistance, hardenability, toughness, thermal stability, compressive strength, and micro-deformation	die and mould components
die steel (M2-hardened and annealed)	tungsten-molybdenum high speed steel	0.85% C, 4% Cr, 6.25% W,5% Mo, 2% V	High hardness and good wear resistance	Twist drills, taps, milling cutters, reamers, broaches, saws, and knives.
Heat treated tool steel	high-carbon, high-chromium, air-hardening tool steel	0.95%C1%Mn0.5%Cr0.5%W0.10%V0.2% Si F	High hardness, strength, and wear resistance.	Rolls, punches, dies for blanking, forming, trimming, and thread rolling
DC53 cold die steel	high alloy tool steel	0 .95%C2.00%Mo8.00Cr0 .25%V	high hardness and toughness	die and tool steels
Cr-Mo-V special steel	low alloy ferritic steel	0.5% C, 7.8% Cr, 1.5% V, 1.5 %Mo	high-temperature suitability and creep-resistance	automobile industry
HOT DIE STEEL	Chromium hot-work tool steels	0.05-0.25%C0.3%Si0.03%Mn1.0%Ni5-13%Cr2.0%Mo1-10%Co0.005-0.05%N Fc	high toughness and fatigue resistance	hot and cold work tooling

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2. Literature Review

Many traditional machining operations, including as turning, milling, drilling, tapping, grinding, honing, and sawing, can be used to manufacture special steels. However, the results show that conventional manufacturing processes cannot machine special steels because of high tool wear, poor machineability, poor surface quality, low accuracy, and the need for more cutting force. As a result, most authors recommended non-conventional machining processes for machining special steels. In the field of WEDM technology, a lot of study has already been done. To the best of my knowledge, no published study on the optimization of numerous performance criteria of the WEDM process has been located. This study examines how to improve WEDM's material removal rate, surface quality, and wire wear ratio by optimizing several performance factors. Table 2 illustrates work done by researchers on various types of special steels, procedures utilized, replies, and important results, which leads to future study opportunities.

Table 2: Different types of steels composition, properties.

S. N.	Author	Steel	Parameters	Techniques used	Responses	Findings
1	Nihat Tosun, Can Cogun	AISI 4140	Pulse duration Open circuit voltage Wire speed flushing pressure	ANOVA	WWR	The effective parameters on WWR are open circuit voltage and pulse duration whereas the effects of dielectric flushing pressure and wire speed are insignificant.
2	Nihat Tosun	AISI 4140	Pulse duration Open circuit voltage Wire speed flushing pressure	regression analysis S/N Ratio	SR CS	The significant parameters on cutting speed and SR are open circuit voltage, pulse duration.
3	Uang, J. T. Liao, Y.H S.	SKD 11 alloy steel	Table feedrate Pulse-on time Pulse-off time Wire velocity Wire tension Fluid pressure	Grey relational analysis S/N ratio	MRR gap width SR	it is found that the table feederate had a significant influence on the MRR, whilst the gap width and SR were mainly influenced by pulse-on time.
4	Ahmet Hasçalýk, Ula¸s Çayda¸	AISI D5 tool steel	Pulse duration Open circuit voltage Wire speed	electron microscopy	Surface morphology SR	Optical and scanning electron microscopy, SR and microhardness tests were used to study the

			flushing pressure		micro hardness	characteristics of the machined specimens.
5	A.B. Puri · B. Bhattacharyya	die steel (M2-hardened and annealed)	Pulse on time	RSM	white layer depth	establish the mathematical model correlating the input process parameters with the response to model the white layer depth through RSM.
			Pulse on time			
			Offset during			
			Constant cutting speed			
6	S. S.Mahapatra, Amar Patnaik	D2 tool steel	Discharge Current	SN Ratio	MRR	Discharge current, pulse duration, and dielectric flow rate and their interactions have been found to play a significant role in maximizations of MRR, minimization of SR and cutting width.
			Pulse Duration			
			Pulse Frequency	GA		
			Wire Speed		SR	
			Wire Tension	Regression Analysis		
			Dielectric Flow Rate			
7	R. Ramakrishnan · L. Karunamoorthy	Heat treated tool steel	pulse on-time	MRSN Ratio	MRR	In the present analysis a very beneficial multi objective optimization tool for manufacturing system especially for WEDM operations has been proposed.
			wire tension			
			Delay time		SR	
			Wire feed speed	ANOVA		
			Ignition current intensity		WWR	
8	K. Kanlayasiri, S. Boonmung	DC53 cold die steel	pulse on time	ANOVA	SR	A mathematical model was developed using multiple regression method to formulate the pulse-on time and pulse-peak current to SR.
			pulse off time	Analysis of residuals		
			pulse-peak current			
			Wire tension	Multiple regression		
9	Ulas Çaydas, Ahmet Hasçalık, Sami Ekici	AISI D5 tool steel	Pulse duration	PCA	SR	An ANFIS model based on both ANN and FL has been developed to predict surface roughness and WLT.
			Open circuit voltage			
			Wire speed	ANFIS	WLT	
			Dielectric flushing pressure			
10	D. V. S. S. S. V.	AISI D3	Pulse-on time	RSM	MRR	Response surface methodology was used to

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	Prasad & A. Gopala Krishna		Pulse-off time wire tension dielectric flow rate wire feed	NSGA	SR	develop the second-order polynomial models for the metal removal rate and the surface roughness in terms of the input variables.
11	J. T. HUANG and Y. S. LIAO	SKD 11 alloy steel	Table feedrate Pulse-on time Pulse-off time Wire velocity Wire tension Fluid pressure	SN Ratio GRA	MRR gap width SR	Grey relational analyses are applied to determine the optimal selection of machining parameters for the Wire-EDM process.
12	Saurav Datta, Siba Sankar Mahapatra	D2 tool steel	Discharge Current Pulse Duration Pulse Frequency Wire Speed Wire Tension Dielectric Flow Rate	RSM GRA	MRR SR Kerf	RSM has been found efficient for prediction of process responses and also application of grey based Taguchi technique has been utilized to evaluate optimal parameter combination to achieve max. MRR, min. SR and min. width of cut.
13	Vijaya bhaskara reddy.P, Vikaram kumar. C.H.R,	Cr-Mo-V special steel	pulse duration open circuit voltage wire speed flushing pressure	ANN Multiple Regression Analysis	SR	Surface roughness is predicted using the multiple regression and Back propagation networks (BPN) and General Regression neural network (GRNN) techniques.
14	Nixon Kuruvila and Ravindra H. V.	HOT DIE STEEL	Pulse-on time Pulse-off time Current Bed speed Flush Rate	Regression Model GA SN Ratio	Dimensional Error (DE) SR VMRR	The results reveal that to go for smaller pulse-off duration for achieving overall good performance and higher values for higher MRR. Smaller current is suggested for better surface finish.
15	Kapil Kumar & Sanjay Agarwal	high-speed steel (M2, SKH 9)	Pulse peak current Pulse duration Pulse-off time Wire feed	SN Ratio NSGA-II	MRR SR	The study reveals that factors like pulse peak current, pulse duration, pulse-off period, wire feed, wire tension and flushing pressure are the primary influencing factors.

			Wire tension			
			Flushing pressure			

3. Summary of Literature Review

Most of the researchers concentrated on process modelling, process parameters, work-piece materials, and other related topics. Using a regression analysis method, Nihat Tosun [2] developed a mathematical relationship between the cutting performance outputs and the cutting parameters. In addition, the variance analysis is used to determine the impact of the cutting parameters on the cutting performance outputs (ANOVA). Grey relational analyses are used to discover the best machining settings, as well as to solve the uncertainty, multi-input, and discrete data problems. The table feed rate had a substantial impact on the metal removal rate, whereas the gap width and surface roughness were predominantly controlled by pulse-on time, according to both Grey relational analysis and a statistical technique [23]. Open circuit voltage and pulse length were shown to be the most effective factors on the WWR using ANOVA and F-test. On the WWR, wire speed and dielectric flushing pressure were ineffective [11]. The surface texture, the number of fissures in the white layer, the surface roughness, and the cutting surface of AISI D5 steel were examined. The heat-affected zone or white layer on the surface has a thickness that is roughly proportionate to the size of the energy impinging on it. Furthermore, depending on the pulse energy, the fractures penetrate the heat-affected zone. When the pulse length and open circuit voltage were increased, the surface roughness increased, even though the cutting surface of all specimens is harder than the bulk material due to the white layer [17]. The predominant input parameters of the WEDM process, which consists of a rough cut followed by a trim cut, have been correlated using mathematical modelling of white layer depth. The experimental investigation was carried out using an experimental plan of rotatable central composite design in RSM, which included four input variables: pulse on time during rough cutting, pulse on time, offset, and cutting speed during trim cutting [21]. Taguchi's parameter design has been proved to be a simple, systematic, reliable, and efficient approach for machining parameter optimization using multi-objective optimization. R. Ramakrishnan and L. Karunamoorthy have provided a multi-objective optimization tool for manufacturing systems, notably for WEDM operations, that is quite beneficial. According to the current research' findings, the optimal parametric combination will be extremely valuable to the industrial communities involved in the WEDM process. The strategy suggested in this work might be used to various non-traditional machining techniques such as electrochemical machining, electron beam machining, laser beam machining, and water jet machining for effective use of such machine tools [10]. Quantitative testing methods were used instead of the traditional qualitative testing approaches to analyses newly created DC 53 die steel. Finally, to relate the pulse-on time and pulse-peak current to the surface roughness, a mathematical model was built utilizing the multiple regression approach. Within the experimental region, the constructed model had a good prediction accuracy [19]. To maximize MRR, SF, and minimize kerf, Taguchi's experimental design technique is applied. Mathematical models are created utilizing the non-linear regression approach in order to optimize for all three objectives. The justification for using a genetic algorithm is that it can identify global ideal parameters, whereas traditional optimization approaches are more likely to find local optimum values [7]. Ulas Aydas, Ahmet Hasçalk, and Sami Ekici developed a technique for predicting surface roughness and WLT in the WEDM process using an adaptive neuro-fuzzy inference system based on complete factorial experimentation. To predict the expected performances, normalization, feature reduction, and ANFIS tests were used. As a result, in the wire electrical discharge machining process, this strategy may considerably enhance process responses such as surface roughness and WLT. To develop mathematical models that emphasize parametric effects on three process responses: material removal rate, surface roughness value, and cut breadth. The Response Surface Method has been shown to be effective in predicting process reactions. The grey-based Taguchi approach was also utilized to find the optimal parameter combination for the maximum MRR, lowest roughness value, and minimum width of cut [12]. Scanning Electron Microscope (SEM) was used to examine the Heat Affected Zone (HAZ) features of the eroded materials, and Vickers microhardness tester was used to test the material's microhardness. The study's findings show that, among the machining parameters, a shorter pulse-off duration is desirable for overall high performance. Higher values for pulse-on time are advised for error constrained machining with higher MRR and constrained limited values for optimal surface texture. For better surface finish texture control, a smaller current is recommended, with a medium range for error control and a high value for MRR [15]. Kapil Kumar, Akshay Dvivedi, and Sudhir Kumar [13] investigated the use of the wire-EDM technique to machine M2-HSS. According to Taguchi's L27 OA, the experiment will be planned. The best machining settings for achieving the lowest GPR were discovered using ANOVA. Using nonlinear regression analysis, mathematical models were created between machining parameters and responses such as metal removal rate and surface quality. To achieve a Pareto-optimal solution set, these mathematical models were subsequently improved using a multi-objective optimization approach based on the Non-dominated Sorting Genetic Algorithm-II [8]. Imtiaz Ali Khan and Tikam Singh Rajput [12] have proposed a method for multi-objective optimization of process parametric combinations using artificial neural networks to represent the WEDM process (ANN) [16].

4. Conclusions

The purpose of this review is to highlight some of the most important WEDM research projects for special steels. Process modelling, process parameters, electrode/tool-work-piece materials, dielectric medium, process parameter optimization, and so on were the subject of previous research projects. Modelling of WEDM is a primary goal, according to the present review research.

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