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Development of Mobile Application in Android, iOS and Windows for Evaluation of Optimal Machining Parameters in WEDM

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Abstract

Wire-EDM is a highly complex machining process, which is characterized by non-linear behavior. Owing to unique capabilities of machining complex shapes and hard materials with high accuracy and fine surface finish, WEDM is used in various manufacturing industries. There has been on-going research to develop automated capabilities for WEDM by understanding the interaction mechanism of various input parameters to get the requisite output measures like MRR, Surface Finish etc. To get the desired output measures, WEDM depends mainly on the operator's experience and trial and error methods. To overcome this, a standard method for predicting output measures/parameters based on the input parameters in WEDM is yet to be developed, which is a key requirement for development of Mobile Application in Android for WEDM. In terms of the smartphone operating system (OS) market Android, Apple, Windows, Blackberry, others have a share of 86.2%, 12.9%, 0.6%, 0.1%, 0.2% respectively. So we chose Android, IOS and Windows as OS for the development of mobile application as they had a big market. In this app, to get the optimal parameters by selecting the material and thickness of workpiece to be machined for the desired parameters like Discharge current, Cutting speed, Spark gap, Material removal rate, Power, and Surface roughness. This application was tested and validated with the Experimental data and additional data in different tool rooms. It is observed that the application results in with the desired accuracy. This application can directly be used in any Android smartphones and tablets. It is a very user-friendly application that would save time, process planning, and also cost.

Keywords: WEDM, OS, Android, iOS, MRR.

INTRODUCTION

Wire Electro Discharge Machining (WEDM) is one of the important non-traditional machining processes which are used for machining difficult to machine materials like HSS, Titanium, Nimonics, Zirconium, etc. Wire-electro discharge machining (WEDM) widely used in the aerospace, nuclear, missile, turbine, automobile, tool and die to make. This is because the WEDM process provides an effective solution for machining hard materials with intricate shapes, which are difficult to the machine through conventional machining methods. [4, 5, 10].

In WEDM the cost of machining is rather high due to high initial investment for the machine and cost of the wire electrode tool. The WEDM process is more economical if it is used to cut difficult to machine materials with complex, precise and accurate contours in low volume and greater variety. WEDM provides high accuracy, repeatability, and a better surface finish but the tradeoff is a very slow machining rate. Due to the slow machining rate in WEDM, machining tasks take many hours depending on the complexity of the job. Due to this, there is a need for the users of WEDM to estimate /predict machining time (in other words the machining rate) along with requisite surface finish, by selecting suitable input parameter values with a pre-programmed system, which may be termed as Expert System for WEDM. Selection of suitable cutting parameters plays an important role in obtaining higher cutting speed or good surface finish. Improperly selected parameters may result in serious consequences like short-circuiting of wire and wire breakage and in turn, reduces productivity. Various investigations have been carried out by several researchers for improving the surface finish and cutting speed of the WEDM process. Even though up-to-date CNC-WEDM machines are available, the problem of selection of cutting parameters in the WEDM process is not fully solved, since so far there is no established standard method for predicting machining rate based on the input parameters because of the complex machining mechanism of WEDM. In addition to this, the recommended input parameter values of the Manufacturers will not yield optimum machining conditions. Hence, there is a heavy dependency on the operators/skilled persons who have hands on the system. Thus the inability to predict efficient automated machining rate has been one of the major obstacles in developing automated process control systems and expert systems for WEDM. [13].

Earlier researchers including me analyzed required process parameters such as machining current, cutting speed, spark gap or over the cut, surface finish and MRR values were explored to develop mathematical correlations, for materials of any thickness ranging from 5mm to 80mm. These parametric settings and outputs were examined and evaluated for a range of materials.

Keeping in view the above mathematical correlations were difficult to remember and to calculate optimum values for any material that usually had long formulae. A mobile application would best suit, to obtain optimum machining parameter values, across various operating systems like Android, IOS (Apple) and Windows. The key objective of the mobile application would be to generate fast calculations. This expert system can be used in both conventional/unconventional systems. These applications can directly be used in any smartphones and tablets. It is a very user-friendly application that would save time, process planning, and also cost. The machining parameters can be set on the machine without trial and error method for the required yield, which in turn increases the accuracy, reduces the machining time and cost.

EXPERIMENTATION DETAILS

Fig. 1a. Shows the schematic diagram of wire electrical discharge machining. Fig. 1b is the photograph represents the pictorial view of wire electrical discharge machine and Fig. 1c shows the sparking taking place during machining.

The parameters set prior to machining are:

Machine	ELCUT 334
Dielectric	De-ionized water
Dielectric Conductivity	38 mhos
Wire Tension	70 N
Wire velocity	3.4 m/min
Wire diameter	0.25 mm
Wire material	66-34 Brass
Gap Voltage	95(Brass), 90(HSS), 85(Graphite), 80(Titanium, Inconel X-750, Copper, Tungsten Carbide, Aluminium, Al-MoS2 MMC), 75(HC-HCr) Volts

The specimens of 20mm x 40mm size on thicknesses 5, 7.5, 10, 12.5, 15, 17.5,20,25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75 and 80mm are prepared. The experiments were conducted on the workpiece of every thickness by cutting 'L' shape and '[' shape by varying the machining current from a lower value to a value where the machining is consistent in 5 steps. At every machining current, I value the machining criteria is measured. The machining current, I value at which the machining is consistent with continuous cutting, better finish with least wire rupture is selected as optimal. The cutting speed is noted from the machine display, surface finish is measured on '[' cut using Talysurf. The cutting width is measured on 'L' cut with shadowgraph and checked with a microscope. The spark gap (wire offset) is calculated from cutting width and MRR is calculated from cutting width. The optimum values of machining current, cutting speed, spark gap and MRR for every thickness are used for plotting the curves and best-fit curve is selected using the Origin 8.0 Pro software. The mathematical relation was generated for this best fit curve and statistical analysis is performed to find the fitness of the curve.

The above experimentation was conducted on HSS, HC-HCr, Titanium, Inconel X-750, Copper, Brass, Graphite, Tungsten Carbide, Aluminium, and Al-MoS2 MMC materials.

Cutting width, W=d+2 Sg, Where d is the wire diameter and Sg is the spark gap.

MRR=T x W x Cs Where Cs is the cutting speed.

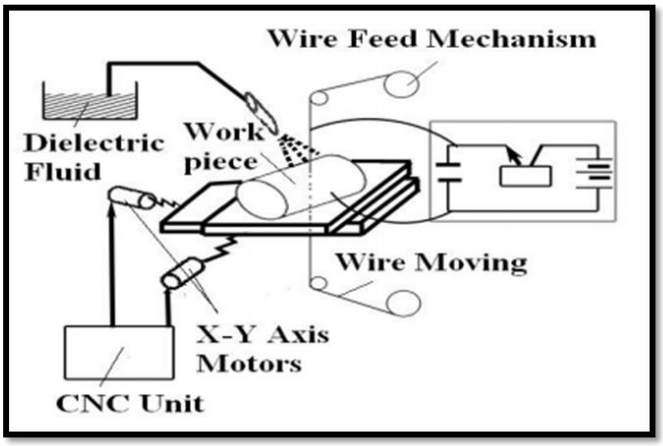

Figure 1a: Schematic view of experimental setup

Figure 1b: Pictorial view of wire electrical discharge machine

Figure 1c: Photograph of spark during machining

Parametric Analysis Based on Experimental Data

Origin 8.0 Pro provides tools for linear, polynomial, and nonlinear curve fitting along with validation and goodness-of-fit tests. We can summarize and present results with customized fitting reports or tables. Curve fitting operations can also be part of an Analysis. Allowing to perform batch fitting operations on any number of data files or data columns. Sigmoidal fitting is a type of analysis that is often used to analyze dose-response relationships, the competition of a ligand for receptor binding. We can perform a dose response curve fit by selecting Fitting: Simple linear regression is a statistical method that allows us to summarize and study relationships between two continuous (quantitative) variables: One variable, denoted x, is regarded as the predictor, explanatory, or independent variable. The other variable denoted y is regarded as the response, outcome, or dependent variable. Because the other terms are used less frequently today, we'll use the "predictor" and "response" terms to refer to the variables encountered in this course. The other terms are mentioned only to make you aware of them should you encounter them in other areas. Simple linear regression gets its adjective "simple," because it concerns the study of only one predictor variable. In contrast, multiple linear regression, which we study later in this course, gets its adjective "multiple," because it concerns the study of two or more predictor variables. The coefficient of determination r2 and the correlation coefficient r quantify the strength of a linear relationship. It is possible that r2 = 0% and r = 0, suggesting there is no linear relation between x and y, and yet a perfect curved (or "curvilinear" relationship) exists. A large r2 value should not be interpreted as meaning that the estimated regression line fits the data well. Another function might better describe the trend in the data. The coefficient of determination r2 and the correlation coefficient r can both be greatly affected by just one data point (or a few data points).Fit Sigmoidal from the main menu. This actually opens the Nonlinear Curve Fitter to the Growth/Sigmoidal category. Then we can select the following function (Eq: 1) in this category to perform the best fitting.

$$y = A_2 + \frac{A_1 - A_2}{1 + e^{\frac{X - X_0}{d_x}}} \qquad \text{(Eq: 1)}$$

Table 1.0 illustrates the values of constants of parametric equation for all materials and parameters including its statistical values.

Table 1: Values of constants for all materials

Material	**Parameter**	**A1**	**A2**	**X_0**	**d_x**	**RMSE**	**R^2**
HSS	I	-2.30275	8.40168	8.95484	18.66664	0.04237	0.99962
	C_s	10456.329	0.39818	-121.31769	15.37933	0.01041	0.98881
	S_g	-1098.77483	112.57393	-342.8435	119.654	0.01642	0.99699
	MRR	2.99423	11.23772	7.5739	4.69665	0.01205	0.95803
	P	-207.24735	756.15126	8.95484	18.66664	0.01813	0.99962
	R_a	1.43415	2.51336	0.00931	20.5254	0.01485	0.9925
HC-HCr	I	-5.19716	7.44402	-8.20928	34.89803	0.00529	0.99999
	C_s	2312.27161	0.18065	-190.03052	27.49036	0.04842	0.99447
	S_g	-23.23916	112.08196	36.37889	61.72579	0.02715	0.99964
	MRR	0.7998	9.65647	10.23356	5.71599	0.08559	0.97661
	P	-345.19353	554.92341	-5.32687	33.81125	0.06916	0.99997
	R_a	1.0419	661.34753	468.96036	72.60049	0.07962	0.98706

Titanium	I	-21.48587	2.68673	-319.6074	109.2219	0.01405	0.99539
	C_s	4.31452	2.83773	39.33753	19.91255	0.02788	0.99562
	S_g	26.3146	61.93124	13.23782	33.45962	0.03409	0.99662
	MRR	-2704.27438	183.56124	-316.48697	117.7659	0.05935	0.99959
	P	-1718.86936	214.93838	-319.6074	109.2219	0.11240	0.99539
	R_a	-975.25978	0.68113	-161.04286	19.47064	0.01664	0.94254
Inconel X-750	I	-5102.29952	5.0203	-223.81707	30.29636	0.01519	0.97177
	C_s	25.88615	0.41922	-21.59079	14.34962	0.07404	0.99629
	S_g	-115644.80731	78.01641	-48.62021	6.62653	0.020303	0.96579
	MRR	4.8799	13.02707	7.57691	1.89794	0.073006	0.97022
	P	-408183.96143	401.62415	-223.81707	30.29636	0.012153	0.97177
	R_a	3.8551	1.26302	14.07248	10.5056	0.07222	0.98997
Copper	I	4.00687	8.52675	64.76446	20.50736	0.03971	0.99853
	C_s	11935.53706	0.58394	-89.7172	10.92178	0.09883	0.97936
	S_g	91.52769	30446.59637	336.06964	37.5576	0.01425	0.9789
	MRR	-1875.42348	23.04561	-271.65383	58.53744	0.02862	0.99574
	P	288.77465	677.80874	53.56094	24.03008	0.05371	0.99659
	R_a	2.25815	2.02752	16.40965	1.04996	0.02238	0.95895
Brass	I	1.57405	8.84769	52.27978	34.18277	0.0695	0.9972
	C_s	21704.12465	1.03147	-102.18205	13.20304	0.02472	0.98764
	S_g	-40863.81003	79.07851	-117.34781	17.73446	0.14018	0.99061
	MRR	-21.06289	26.65285	-2.90921	8.64783	0.026086	0.7583
	P	69.37475	734.91228	32.47123	33.54709	0.153578	0.9847
	R_a	3.34859	2.12246	23.07471	10.51202	0.04846	0.98768
Graphite	I	-7452.70008	3.92677	-193.0506	25.28103	0.017949	0.96952
	C_s	6001.5674	0.25004	-79.08977	9.94361	0.04743	0.98731
	S_g	-141452.1689	123.37932	-100.92568	14.36478	0.018465	0.99637
	MRR	-7.48772	8.90625	-19.05837	41.6981	0.00953	0.99997
	P	-634112.56549	333.78144	-193.13133	25.28755	0.05269	0.96945
	R_a	2.19364	0.89183	75.03545	23.41655	0.04688	0.96162
Tungsten Carbide	I	-301.0548	11.6944	-364.91859	106.67627	0.o11725	0.99542
	C_s	7910.52003	0.20526	-81.10173	9.69766	0.06151	0.97342
	S_g	-8786.65331	91.06823	-341.62406	63.46498	0.010322	0.98855
	MRR	-3127.04169	5.05219	-186.27911	27.1488	0.017155	0.96807
	P	-24084.38422	935.55172	-364.91859	106.67627	0.0938	0.99542
	R_a	720.5512	1.25157	-128.8833	15.46047	0.011181	0.93408
Aluminium	I	-287.83136	1.54617	-359.53582	64.22677	0.03175	0.98381
	C_s	445.96159	0.21629	-396.90872	79.26225	0.07092	0.98694
	S_g	-8105.44176	45.71537	-85.94049	14.85046	0.071463	0.98671
	MRR	-7.33212	35.05325	17.1335	14.21831	0.051843	0.99801
	P	-22537.72631	123.71078	-358.17923	64.23433	0.02533	0.9839
	R_a	720.5512	1.25157	-128.8833	15.46047	0.01181	0.93408
Al-MoS2 MMC	I	-449.32208	12.56303	-395.49787	95.85084	0.01191	0.99241
	C_s	5329.18684	1.25603	-121.81937	17.54991	0.017999	0.98255

	S_g	304941.20648	4.99413	-43.66972	5.58618	0.029191	0.96254
	MRR	7.61815	22.87292	22.17531	11.75745	0.022061	0.84011
	P	-35945.76668	1005.04257	-395.49787	95.85084	0.095282	0.99241
	R_a	2.61534	6.10731	20.51324	16.21468	0.010389	0.98855

Lower values of RMSE indicate better fit. RMSE is a good measure of how accurately the model predicts the response and is the most important criterion for fit if the main purpose of the model is a prediction.

R-square (R2) has the useful property, it ranges from zero to one, with zero indicating that the proposed model does not improve prediction over the mean model and one indicating perfect prediction. If the R-square value is close to one indicates the goodness of fit of the model.

Working of Mobile App

Fig.2.0 represents the screenshot about downloading process of the mobile app from Google play store by searching with name iWEDM, Fig 3.0 shows screenshot depicting the application software according to present invention or installed app in the smart device and Fig 4.0 represents the about information of the app.

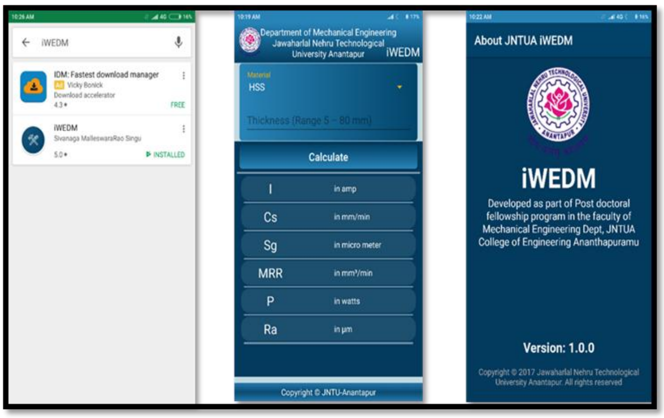

Figure 2.0 **Figure 3.0** **Figure 4.0**

Select the type of material to manufacture, enter thickness of the material selected in the range of 5 to 80 mm and by clicking on Calculate button parameters will be populated as shown in Fig 5.0.

Figure 5.0

Validation

The following table 2.0 illustrates validity of the parameters developed is checked by performing experiments on work pieces of 25mm and 65mm thickness. The experimental results and results obtained from the mobile application shows a small variation of 2% only. This proves authenticity of the correlations used in the mobile application.

Table 2: Values of constants for all materials

HSS	**T, mm**	**I, amp**	**C_{s}, mm/min**	**S_g, µm**	**MRR, mm³/min**	**P in W**
Exp	25	5.2	1.23	59.08	11.32	468
Mob App		5.21786	1.19995	59.05292	11.23772	469.60705
Exp	65	7.95	0.42	73.72	10.85	715.50
Mob App		7.89518	0.45545	73.77246	11.23772	710.5661
HC-HCr	**T, mm**	**I, amp**	**C_{s}, mm/min**	**S_g, µm**	**MRR, mm³/min**	**P in W**
Exp	25	3.92	1.1	38.22	8.97	294
Mob App		3.92268	1.10698	38.20253	9.03458	294.17891

Exp	65	6.07	0.4	59.57	9.59	455.25
Mob App		6.06221	0.39691	59.83274	9.65586	454.95866
Titanium	**T, mm**	**I, amp**	**Cs, mm/min**	**Sg, µm**	**MRR, mm^3/min**	**Power, P W**
Exp	25	1.7	3.859	47	33.162	136
Mob App		1.69831	3.83104	47.22119	32.90897	135.86441
Exp	65	1.98	3.17	55.37	75.538	158.4
Mob App		1.99271	3.15681	55.67983	74.65852	159.41660
Inconel X-750	**T, mm**	**I, amp**	**Cs, mm/min**	**Sg, µm**	**MRR, mm^3/min**	**Power, P W**
Exp	25	3.6	1.4	74	13.93	288
Mob App		3.63573	1.37273	76.28486	13.02707	290.85886
Exp	65	4.6	0.47	79.2	12.47	368
Mob App		4.65047	0.48007	78.01227	13.02707	372.03755
Graphite	**T, mm**	**I, amp**	**Cs, mm/min**	**Sg, µm**	**MRR, mm^3/min**	**Power P, W**
Experimental	25	2.7	0.47	101.72	4.67	229.5
Mob App		2.58819	0.42066	101.31081	4.67728	219.99842
Experimental	65	3.66	0.22	122.46	6.99	311.1
Mob App		3.65163	0.25310	122.01629	6.97921	310.38393
Aluminum	**T, mm**	**I, amp**	**Cs, mm/min**	**Sg, µm**	**MRR, mm^3/min**	**Power P, W**
Experimental	25	0.84	2.3	42	19.2	67.2
Mob App		0.82142	2.38024	41.07480	34.82346	65.70611
Experimental	65	1.15	1.52	44.5	33.49	92
Mob App		1.15693	1.52522	45.40130	35.05325	92.55528
Copper	**T, mm**	**I, amp**	**Cs, mm/min**	**Sg, µm**	**MRR, mm^3/min**	**Power P, W**
Experimental	25	4.55	1.08	100	10.69	391
Mob App		4.57526	0.91142	99.20294	11.16670	379.62129
Experimental	65	6.4	0.56	117	18.43	531.25
Mob App		6.27979	0.59235	113.78230	17.02888	528.73484
Brass	**T, mm**	**I, amp**	**Cs, mm/min**	**Sg, µm**	**MRR, mm^3/min**	**Power P, W**
Experimental	25	3.9	2.5	66	23.87	370.95
Mob App		3.83209	2.45388	65.70889	24.83245	365.24066
Experimental	65	6	0.94	77	24.56	570
Mob App		5.87984	1.10023	77.67668	26.63431	551.92190
Tungsten Carbide	**T, mm**	**I, amp**	**Cs, mm/min**	**Sg, µm**	**MRR, mm^3/min**	**Power P, W**
Experimental	25	3.74	0.44	60	4.07	299.2
Mob App		3.81134	0.34541	63.64612	3.74644	304.90700
Experimental	65	6.16	0.18	82	4.84	492.8
Mob App		6.23323	0.20753	76.44625	4.75288	498.65831
Al-MoS2 MMC	**T, mm**	**I, amp**	**Cs, mm/min**	**Sg, µm**	**MRR, m^3/min**	**Power P, W**
Experimental	25	6.98	2.45	10.105	16.02	558.4
Mob App		6.88870	2.49548	6.39216	16.60458	551.09631
Experimental	65	8.81	1.516	3.52	24.65	704.8
Mob App		8.80897	1.38293	4.99522	22.87292	704.71791

ADVANTAGES & CONCLUSIONS

This app will save time, process planning and cost.

Using this app we can find the machining parameters and same can be set on the machine without trial and error method for required yield.

We applied for patent having application number 201741018671 and status is Application Awaiting for Examination.

App was tested in user and manufacturer perspective. Got good feedback and recommendations too from them.

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