Wire Electrical Discharge Turning Of Inconel 751

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***ABSTRACT*:** In this work, material removal rate (MRR), surface roughness (Ra) on the wire electrical discharge turning of Turning with Wire electrical discharge machining of Inconel 751 has been carried out. Turning with Wire electrical discharge machining process was designed and developed to generate precise cylindrical forms on complicate, hard and difficult to cut fragile materials. This study has been carried out on the influence of design factors such as rotational Speed, Voltage, Pulse-On Time, and Pulse-Off Time which are the most relevant parameters to be controlled by the TWEDM process machinists. Experiments are designed to perform less number of experiments by using design of experiments (DOE). In this case, an L_9 Taguchi standard orthogonal array was chosen due to the number of factors and their levels in the study. ANOVA is performed to find the relation between input parameters and output parameters and then to find the most influencing input parameters of the process. Gray Relational Analysis method is deploy an effective tool for both single response and multi-response optimization of TWEDM process.

Index Terms: WEDM (Eectronica Sprint cut 734), Inconel-751,Mituthoyo Surface roughness tester, MRR,S/n ratio, Brass wire.

1. INTRODUCTION

Electrical discharge machining is used for cutting of electrically conductive materials. It is suitable for heavy machining as well as manufacturing delicate parts since the machining energy involved during the process can be very low compared with other conventional machining methods. Wire electrical discharge machining (WEDM) is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the main stream machining processes.

2. MATERIAL AND METHODOLOGY

Eectronic sprint cut 734

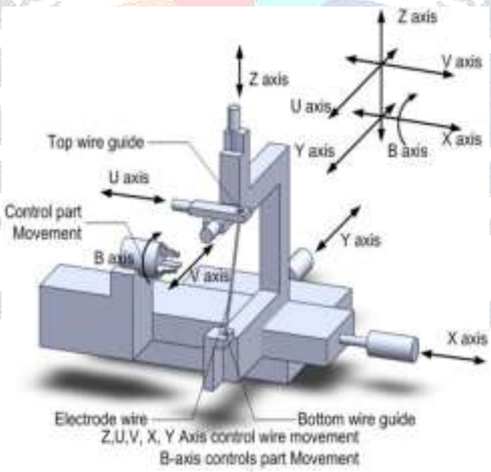
Brass Wire

TOOL: Brass wire (Thickness=0.25mm).

OPERATION: Cylindrical wire Electrical discharge turning.

WORK PIECE: Inconel 751

WORK PIECE DIMENSION: 200 mm length, 10 mm diameter.



Mechanism of Wire electric discharge machining

Wire electric discharge turning is one of the emerging area developed to generate cylindrical form on hard and difficult to cut nickel alloy such as Inconel 751. In this process the electrical discharge takes between the travelling wire and the rotating work piece to be machined .In this process the desired cylindrical forms can be obtained by controlling the electrically charged wire X and Y directions to remove the unwanted work material.

S.NO	PARAMETERS	UNITS	NOTATIONS	LEVELS		
				1	2	3
1.	Spindle speed	rpm	X1	10	20	30
2.	Pulse on time	µs	X2	100	110	120
3.	Wire feed	m/min	X3	5	10	15
4.	Servo voltage	v	X4	10	15	20

Machining Parameters and levels

S.No	Spindle	Pulse on time	Wire feed	Servo voltage
1.	1	1	1	1
2.	1	2	2	2
3.	1	3	3	3
4.	2	1	2	3
5.	2	2	3	1
6.	2	3	1	2
7.	3	1	3	2
8.	3	2	1	3
9.	3	3	2	1

L9 orthogonal array for experimentation

3. Experimental setup

The experiment is conducted on Sprint cut high precision 5-axis Computer Numeric Control Wire electric discharge turning. The Wire electric discharge turning equipped with a rotary axis in order to produce cylindrical forms. Inconel 751 is a work piece of 10mm diameter with 200mm length used to perform turning experiments on Wire electric discharge turning.

Experimental setup of WEDT process

Surface roughness tester

The Computer Numeric Control wire Electron Discharge Machining machine is equipped with the servo-motor (with 3-Phase power supply) and a slab equipped with guided pulleys which are connected to each other by a belt for the rotary movement of the work piece for machining it.. In this Phase of experimentation a design of experimentation technique by L9 orthogonal array has been used for studying the influence of 4 process parameters(Spindle speed, Pulse-on time, wire feed ,servo) on two different responses Material removal rate and surface roughness (Ra) during machining Inconel 751.experiments are performed at three different levels 9 Experiments are performed.

4. CALCULATION OF METAL REMOVAL RATE

$$\text{Metal Removal Rate} = \frac{\textbf{initial weight} - \textbf{final weight}}{\textbf{Machining time}} \text{ gm/min} \; ..... \text{Eq.1}$$

1. Metal Removal Rate = (13.886-12.840)/18.23= 0.057 gm/min
2. Metal Removal Rate = (14.005-13.650)/12.56 = 0.028 gm/min
3. Metal Removal Rate = (14.066-13.779)/ 19.22= 0.014 gm/min
4. Metal Removal Rate = (14.090-13.759)/ 13.33= 0.02483 gm/min
5. Metal Removal Rate = (14.036-13.612)/ 17.06= 0.02485 gm/min
6. Metal Removal Rate = (14.055-13.693)/ 20.06= 0.0180 gm /min
7. Metal Removal Rate = (14.002-13.818)/ 12.30= 0.0149 gm /min
8. Metal Removal Rate = (14.005-13.590)/ 19.07= 0.0217 gm/min
9. Metal Removal Rate = (18.457-18.333)/ 15.21= 0.015 gm/min

4.1 S/N Ratio:

S/N RATIO: -10log $[\frac{1}{n}(\sum y_i^2)]$ (Surface roughness) … Eq.2

S/N RATIO: -10log $[\frac{1}{n}(\sum 1/y_i^2)]$ (Metal removal rate) … Eq.3

S.No	Spindle	Pulse on time	Wire feed	Servo voltage	S.R	MRR
1.	10	100	2	10	4.895	0.018
2.	10	110	3	15	5.682	0.014
3.	10	120	4	20	6.37	0.015
4.	20	100	4	20	4.32	0.021
5.	20	110	3	10	5.146	0.057
6.	20	120	2	15	5.59	0.024
7.	30	100	4	15	4.692	0.024
8.	30	110	2	20	4.904	0.028
9.	30	120	3	10	5.744	0.014

Experimental Data Related to Surface Roughness Characteristic

4.2 CALCULATIONS OF S/N RATIO FOR SURFACE ROUGHNESS

S/N RATIO: -10log $[\frac{1}{n}(\sum y_i^2)]$ …. Eq.4

1. S/N Ratio (Experiment1)=$\eta 1$=-10 log[1/1(4.895)^2] =-13.79
2. S/N Ratio (Experiment2)=$\eta 2$=-10log[(5.682)^2] = -15.090
3. S/N Ratio(Experiment3)=$\eta 3$=-10log[(6.37)^2] = -16.082
4. S/N Ratio (Experiment4)=$\eta 4$=-10log[(4.32)^2] =-12.706
5. S/N Ratio (Experiment5)=$\eta 5$ =-10log[(5.146)^2] = -14.229
6. S/N Ratio(Experiment6)=$\eta 6$=-10log[(5.59)^2] = -14.948
7. S/N Ratio(Experiment7) =$\eta 7$=-10log[(4.692)^2] = -13.427

8. S/N Ratio (Experiment8)=η8=-10log[$(4.904)^2$] = - 13.811

9. S/N Ratio (Experiment9)=η9=-10log[$(5.744)^2$] = - 15.184

4.2 CALCULATIONS OF S/N RATIO FOR MRR

S/N RATIO: -10log $[\frac{1}{n}(\sum 1/y_i^2)]$ ….. Eq.5

1.S/N Ratio (Experiment1) = η1=-10log [1/n (∑1/Yi^2)]=-10log[1/$(0.0180)^2$] = -34.894

2. S/N Ratio(Experiment2)=η2=-10log[1/$(0.0140)^2$]=-37.077

3. S/N Ratio(Experiment3)=η3=-10log[1/$(0.0150)^2$]=-36.478

4. S/N Ratio(Experiment4)=η4=-10log[1/$(0.0217)^2$]=-33.270

5. S/N Ratio(Experiment5)=η5=-10log[1/$(0.0570)^2$]=-24.882

6. S/N Ratio(Experiment6)=η6=-10log[1/$(0.02485)^2$]=-32.093

7. S/N Ratio(Experiment7)=η7=-10log[1/$(0.02483)^2$]=-32.100

8. S/N Ratio(Experiment8)=η8=-10log[1/$(0.0280)^2$]=-31.056

9. S/N Ratio(Experiment9)=η9=-10log[1/$(0.0149)^2$]=-36.536

7. RESULTS AND ANALYSIS

S/N RATIO OF SURFACE ROUGHNESS (Ra)	S/N RATIO OF METAL REMOVAL RATE (MRR)
-13.79	-34.894
-15.090	-37.077
-16.082	-36.478
-12.706	-33.270
-14.229	-24.882
-14.984	-32.093
-13.427	-32.100
-13.811	-31.056
-15.184	-36.536

Determination of optimized values

8. REGRESSION ANALYSIS SOURFACE ROUGHNESS V/S SPINDLE SPEED,PULSE ON TIME,WIRE FEEDPERFORMED IN ANNOV:

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	2.93137	0.73284	9.73	0.024
spindle speed (rpm)	1	0.43041	0.43041	5.72	0.075
pulse on time	1	2.49428	2.49428	33.13	0.005
wire feed (m/min)	1	0.09201	0.09201	1.22	0.331
servo voltage (v)	1	0.03095	0.03095	0.41	0.556
Error	4	0.30115	0.07529		
Total	8	3.23252			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.274385	90.68%	81.37%	49.09%

Coefficients

Term		Coef	SE Coef	T-Value	P-Value	VIF
Constant		-1.58	1.38	-1.15	0.316	
spindle speed	(rpm)	-0.0268	0.0112	-2.39	0.075	1.00
pulse on time		0.0655	0.0114	5.76	0.005	1.03
wire feed (m/min)		0.133	0.121	1.11	0.331	1.16
servo voltage	(v)	-0.0153	0.0238	-0.64	0.556	1.13

Regression Equation without backward elimination:

SR = -1.58 - 0.0268 spindle speed (rpm) + 0.0655 pulse on time + 0.133 wire feed (m/min)- 0.0153 servo voltage (v)

By substituting the optimal values

SR = 6.314

8.2 Regression Equation with backward elimination:

SR = -1.17 - 0.0268 spindle speed (rpm) + 0.0633 pulse on time

SR= 6.158

9. REGRESSION ANALYSIS: METAL REMOVAL RATE (WEIGHT) V/S SPINDLE SPEED, PULSE ON TIME, WIRE FEED

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	
Regression	4	0.001300	0.000325	11.81	0.017
spindle speed (rpm)	1	0.000374	0.000374	13.61	0.021
pulse on time	1	0.000517	0.000517	18.80	0.012
wire feed (m/min)	1	0.000307	0.000307	11.17	0.029
servo voltage (v)	1	0.000064	0.000064	2.34	0.201
Error	4	0.000110	0.000028		
Total	8	0.001410			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0052462	92.19%	84.38%	42.09%

Coefficients

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Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.1772	0.0264	6.72	0.003	
spindle speed (rpm)	-0.000790	0.000214	-3.69	0.021	1.00
pulse on time	-0.000944	0.000218	-4.34	0.012	1.03
wire feed (m/min)	-0.00771	0.00231	-3.34	0.029	1.16
servo voltage (v)	-0.000696	0.000455	-1.53	0.201	1.13

9.1 Regression Equation without backward elimination:

Metal Removal rate (Weight) (gm/min) = 0.1772 - 0.000790 spindle speed (rpm) - 0.000944 pulse on time - 0.00771 wire feed (m/min) - 0.000696 servo voltage (v)

By substituting the optimal values

Metal Removal Rate = 0.01476 gm/min

9.2 **Regression Equation with backward elimination:**

Metal Removal Rate (gm/min) = 0.1726 - 0.000790 spindle speed (rpm) - 0.000963 pulse on time - 0.00891 wire feed (m/min)

Metal Removal Rate= 0.01523 gm/min

9. CONCLUSION

In this work, an attempt was made to determine the important machining parameters for performance measures like MRR and Surface roughness separately in the WEDT process. Factors like spindle speed, pulse-on time and wire feed have found to play a significant role in rough cutting operations for maximizations of MRR, minimization of surface roughness. The optimal parameters set are SS2Ton2WF3SV1 found from the response graphs. Taguchi experimental design method is used to obtain optimum parameter combination for maximization of MRR and minimization of SR. in order to optimize for all the two objectives, mathematical models are developed using the regression method.

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