OPTIMIZATION OF PROCESS PARAMETERS IN MACHINING OF 6063 ALUMINIUM ALLOY USING RSM

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Abstract:

Due to global competition in manufacturing industries scenario the conventional machining processes have been replaced by advanced non-conventional machining process. Several advanced non-conventional machine tools are available specifically computer numerical control (CNC) turning is the major used machine tool in metal based industries. Now days, due to the increasing demand of the higher precision components for its functional aspect, surface roughness of a machined part plays an important role in the modern manufacturing process. To get the minimum surface roughness various turning parameter like cutting speed, depth of cut, feed rate, metal removal rate (MRR) and tool geometry etc. are required among all these parameter optimal parameter are determined by using various optimization techniques. Productivity as well as quality both has a similar impact on final product. This paper describes various optimization studies and the literature review for the influence of CNC turning parameter on surface roughness as well as other response variables.

1.0 Introduction

Aluminum alloys are contains the typical alloy elements such as copper, magnesium, manganese, silicon and zinc and in which aluminum is the predominant metal. Here aluminum 6063 is the work piece material and CCMT is cutting tool. The main properties of aluminum are light weight, strength, recyclability corrosion resistance, durability, formability, ductility and conductivity which make them valuable material. Surface roughness is one of the importantrequirements in machiningprocess.

Turning

Turning is the process whereby a single point cutting tool is parallel to the surface. It can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator,or by using a computer controlled and automated lathe which does not. This type of machine tool is referred to as having computer numerical control, better known as CNC, and is commonly used with many other types of machine tool besides the lathe. When turning, a piece of material (wood, metal, plastic even stone) is rotated and a cutting tool is traversed along 2 axes of motion to produce precise diameters and depths.

Overview of Wire

EDM Wire EDM (Vertical EDM's kid brother), is not the new kid on the block. It was introduced in the late 1960s', and has revolutionized the tool and die, mold, and metalworking industries. It is probably the most exciting and diversified machine tool developed for this industry in the last fifty years, and has numerous advantages to offer. WEDM is a spark erosion process used to produce complex two and three dimensional shapes through electrically conductive work pieces. The wire does not touch the work piece, so there is no physical pressure imparted on the work piece compared to grinding wheels and milling cutters.

2.0 literature review

P. Saha, D. Tarafdar, (2009) In this paper, an attempt has been made to machine Al

6063/ $ZrSiO_4$ (p) metal matrix composite using wire electric discharge machining. The objective is to investigate the influence of process parameters namely pulse on time, pulse off time, peak current and servo voltage on dimensional deviation. A Box-Behnken design approach of response surface methodology (RSM) is used to plan and analyze the experiments.

N.G. Patil, P.K. Brahmankar (2010) Every manufacturing industry aims at producing a large number of products within relatively lesser time. This study applies Taguchi design of experiment methodology for optimization of process parameters in turning of Aluminium Alloy 7075 using tungsten coated carbide tool. Experiment have been carried out based on L27 standard orthogonal array design with three process parameters namely Cutting Speed, Feed, Depth of Cut for Material removal rate and Machining time.

A. Shah, N.A. Mufti, (2010) Wire-Electrical Discharge Machining (WEDM) is an extremely accurate machining process. It can produce a smooth surface finish as the wire is able to go through the entire part and the accuracy can be achieved until ×0.0001 inches. WEDM is also very effective in machining of small holes, blind holes, inclined holes, irregular holes and deep holes. Aluminium 6063 is perhaps the most widely used workpiece because of its extrudability.

S.K. Garg, A. Manna, A. Jain (2016) Turning is one of the widely used machining processes for various purposes. The purpose of turning operation is to produce low surface roughness of the parts. In a global competitive environment every industry are trying to reduce the cutting cost and improved the quality of machined parts/components. So, it required focusing on material removal rate and surface roughness .Critical quality measure and surface roughness in mechanical parts depends on process parameter during machining parameter.

E. Hamed, A. Sarkar (2001) This paper presents the effect of process parameter in turning operation to predict surface roughness. The turning process by using CNC turning lathe is widely used in industry because of its versatility and efficiency. Applications of the turning process can be found in many industries ranging from large engine manufactures to small die shops. The parameters that affect the turning operation are vibration, tool wear, surface roughness etc

3.0 Methodology

A wire EDM machine (Sprintcut 734) was utilized for test examination. This machine gives full scope of adaptability to the administrator in choosing parameters esteems. The settled procedure parameters are: Workpiece: Aluminum amalgam 6063, Cathode: 0.25mm Ø metal wire, workpiece tallness: 15mm, cutting length: 100mm, dielectric conductivity: 20mho, dielectric temperature: 20- 24°C. Table 1 demonstrates the huge control factors, their units and breaking points.

Table Optimal Ranges of Significant Process Parameters

Real factor	Unit	Parameter Name	Lower Limit	Upper Limit
Ton	Pulse on Time	µs	100	104
Toff	Pulse off time	µs	40	60

WF	Wire Feed	m/min	6	12
SV	Servo Voltag e	V	45	75

Experimental set-up:

A Kistler force three component dynamometer (Type 9215A1, calibrated range: Fx.0±5000 N,Fy.0±5000 N, and Fz.0±3000 N) in conjunction with three Kistler charge amplifiers (Type 5070), used to convert the dynamometer output signal into a voltage signal appropriate for the data acquisition system, and a computer were used to measure and record the cutting forces. The instrument shown in figure 1 is a Kistler three component dynamometer and the figure is a multi-channel charge amplifier.

Figure:Kistler Three component Dynamometer

Thermocouples are known to be very popular transducers for measuring temperature. The k-type thermocouple was chosen for measuring the temperature in this work. This technique was preferred as it is inexpensive, easy to calibrate, has a quick response time and good repeatability during experiments. A mineral insulated, metal sheathed, k-type thermocouple with Digital micro voltmeter of ranges between -200°C and 1200°C.

Work Material

The work material used as the test specimen was Aluminium 6063. A cylindrical bar of Aluminium alloy (320mm long 60 mm diameter) was used for the tests.

Tool Material

Tungsten carbide inserts were used for the turning tests. These inserts are manufactured by Sandvik. Uncoated carbide inserts as per ISO specification THN SNMG 08 were clamped onto a tool holder with a designation of DBSNR 2020K 12 for turning operation. The parameter levels were chosen within the intervals based on the recommendations by the cutting tool manufacturer.

Design of Experiment

A commercial statistical analysis software "Design Expert" was employed for design of experiment. In Design Expert, RSM is used to find a combination of factors which gives the optimal response. RSM is actually a collection of mathematical and statistical technique that is useful for the modeling and analysis of problems in which a response of interest is influenced by several variables and the objectives is to optimize the response. Three process parameters at three levels led to a total of 27 tests for turning operation. Three levels were specified for each of the factors as indicated in Table. The standard orthogonal array chosen was L27, which has 27 rows and 26 degrees of freedom.

Table Factors and Levels

Factor	Assignme nt	Levels		
		Lev el 1	Lev el 2	Lev el 3
Speed(N) m/min	A	100	150	200
Depth of cut(d)mm	B	0.25	0.5	1
Feed	C	0.05	0.07	0.1

rate(f)mm/rev			5	

Taguchi Approach

Taguchi method uses a loss function to determine the quality characteristics. Loss function values are also converted to a signal-to-noise (S/N) ratio η. The term "signal" represents the desirable value (mean) for output characteristic and the term "noise" represents the undesirable value for the output characteristic. Usually there are three categories of the performance characteristic in the analysis of the S/N ratio, that is, the lower-the-better, nominal-the-better and the higher-the-better. The S/N ratio for each level of process parameters is computed based on the S/N analysis. The optimal level of the process parameters is the level having highest S/N ratio.

Aluminium 6063T6 before machining

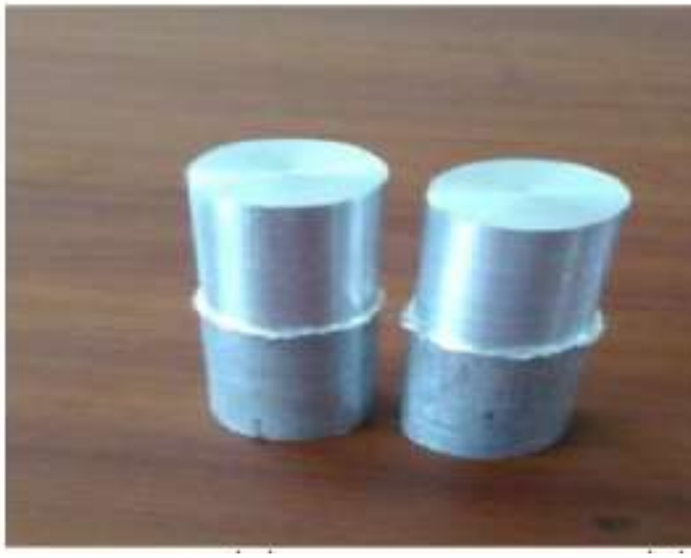
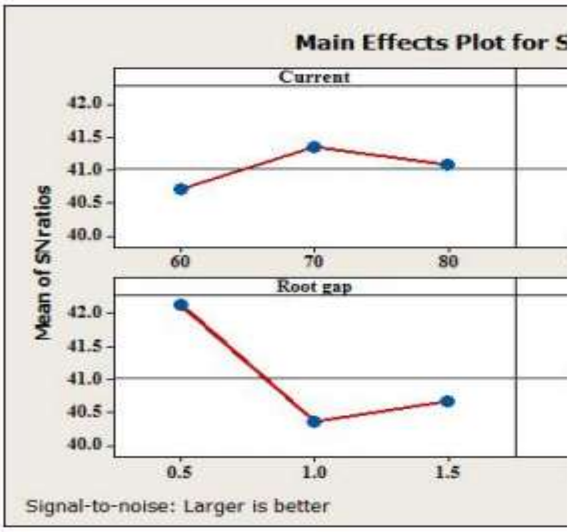


Figure Aluminium 6063T6 after machining

4.0 Analysis of micro-hardness

The micro-hardness testing as carried out on different welded specimens. Figure 2 and table 4 showing that the most influencing factor for the hardness property is welding voltage at higher level (50 V) of voltage. The second affecting factor is root gap at its first level i.e. 0.5 mm, third affecting factor is welding current at its second level (70 A), and finally the last affecting factor is gas flow rate at its first level (16 litter/min). To validate the above result analysis of variance (ANOVA) was applied which is presented in table.



Graph: Main effects plot for SN ratios for hardness property

R 2 (Coefficient of determination) is used to check the goodness of the model; it determines how close the predicted values with the experimental values [6,14]. The values of R 2 are mentioned in Table, for the hardness value R-sq = 97.13 and R- sq (adj) = 96.27. This value indicates the goodness of designed model at states that designed model is valid for the further investigation.

Table Response table for S/N ratio of hardness value

Level	Current	Voltage	Root Gap	Gas flow rate
1	40.72	39.96	42.14	41.12
2	41.36	41.30	40.38	41.07
3	41.08	41.92	40.68	40.87
Delta	0.64	1.95	1.77	0.25
Rank	3	1	2	4

Table Analysis of variance Hardness

Source	DOF	Adj SS	Adj MS	F-Value	P-Value
Linear	4	2851.57	712.89	106.91	0.00
I	1	102.15	102.154	15.32	0.002
V	1	42.94	42.936	6.44	0.026
R	1	37.95	37.948	5.69	0.034
G	1	0.44	0.440	0.07	0.802
Square	4	1316.81	329.204	49.37	0.0000

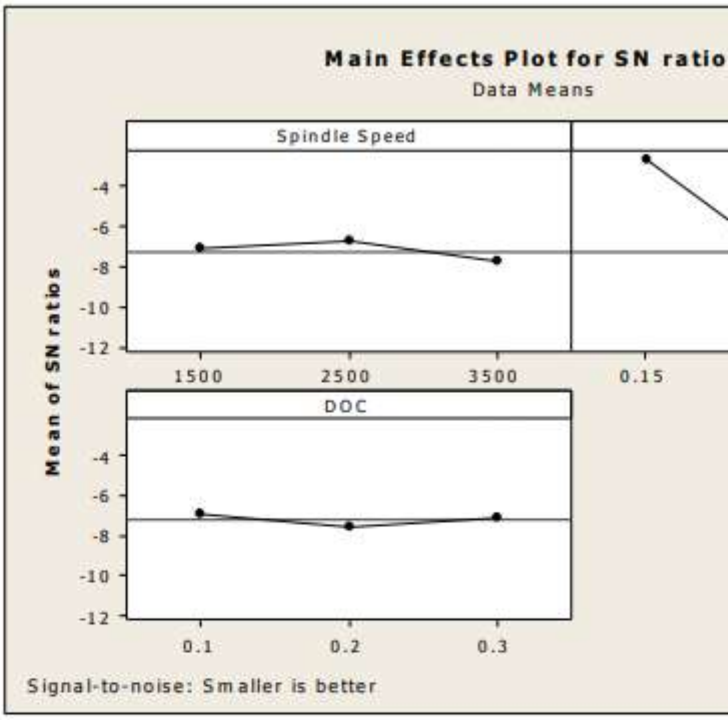
A series of experiments have been carried out with variation of different parameters. After completing the experiments according to design of experiment a statistical analysis was done for the experimental data obtained which are shown in table from the L27 experiments. The average performance and S/N ratio were calculated for surface roughness. Analysis of variance (ANOVA) was performed to identify the most significant control parameter and to quantify their effects on surface roughness.

Table Surface Roughness and S/N ratio according to Design of Experiment

Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)	Ra (µm)	S/N Ratio
1500	0.15	0.1	2.4954	-7.9428
1500	0.15	0.3	1.0507	-0.4296
1500	0.15	0.6	1.1099	-0.9057
1500	0.25	0.1	2.4307	-7.7146
1500	0.25	0.3	2.4440	-7.7620

Table ANOVA for s

Source	DOF	Seq SS	Adj SS	Adj MS	F	P	% contribution
Speed	2	2.9651	2.6682	1.3341	2.71	0.126	6.66376
Feed	2	22.6838	21.1463	10.57315	21.48	0.001	50.97953
Doc	2	0.1115	0.1067	0.05335	0.11	0.899	0.250585
speed*feed	4	7.4175	5.6740	1.4185	2.88	0.095	16.67008
speed*doc	4	3.2074	3.6386	0.90965	1.85	0.213	7.208305



4.1.3 Graph S/N Response Graphs for Surface Roughness

Conclusion:

The revelations from the past data for over two decades prove that Computer Numerical Controlled (CNC) machine plays an important role in advanced manufacturing industries. Productivity as well as product quality also plays a vital role in competitive manufacturing. After literature review major three factors like cutting speed, depth of cut and feed rate are more responsible for surface roughness because finally that parameter gives the surface quality of CNC turning work-piece. In this situation the selection of optimization method and determination of optimum machining parameter condition is very crucial. Hence this paper provide a package round study about the effect of turning process parameter on surface roughness of CNC turning work-piece and their measurement methods as well as process parameters optimization techniques (Taguchi techniques has been used regularly to optimize the process parameter). The analysis has highlighted certain point: Genesis of analysis points out that the following techniques have been adopted for optimization of turning process parameter:

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