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Due to global competition in manufacturing industries scenario the conventional machining processes have been replaced by advanced non-conventional machining process.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.

Keywords*:CNC, MRR, RSM*

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. Cutting condition include speed, feed rate and depth of cut. An important aspect of RSM is the design of experiments usually abbreviated as DOE. These strategies were originally developed for the model fitting of physical experiments, but can also be applied to numerical experiments. The objective of DOE is the selection of the points where the response should be evaluated.

Traditional experimental design methods are very complicated and difficult to use. Additionally, these methods require a large number of experiments when the number of process parameters increases. In order to minimize the number of tests required, Taguchi experimental design method, a powerful tool for designing high quality system, was developed by Taguchi. This method uses a special design of orthogonal arrays to study the entire parameter space with small number of experiments only.

Computer numerical control

Numerical Control is the automation of machine tools that are operated by precisely programmed commands encoded on a storage medium, as opposed to controlled manually via hand wheels or levers, or mechanically automated via cams alone. Most NC today is computer numerical control (CNC), in which computers play an integral part of the control. In modern CNC systems, end-to-end component design is highly automated using computer-aided design (CAD) and computer-aided manufacturing (CAM) programs

Various cycles:

- turning
- milling
- Measurement

Figure: FANUC control LCD

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.

Cutting tools:

Cutting is the separation of a physical object, or a portion of a physical object, into two portions, through the application of an acutely directed force. An implement commonly used for cutting is the knife or in medical cases the scalpel. However, any sufficiently sharp object is capable of cutting if it has a hardness sufficiently larger than the object being cut, and if it is applied with sufficient force. Cutting also describes the action of a saw which removes material in the process of cutting.

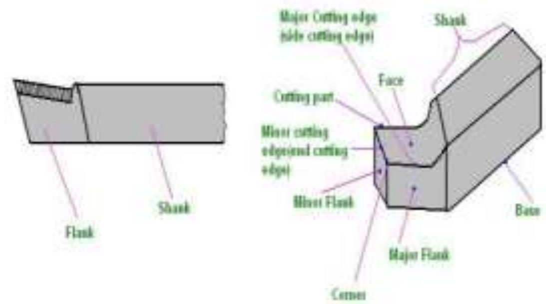


Figure: Single point cutting tool

The materials used in airframe structures and in jet engine components are critical to the successful design, construction, certification, operation and maintenance of aircraft . Materials have an impact through the entire life cycle of aircraft, from the initial design phase through manufacture and certification of the aircraft, to flight operations and maintenance and, finally, to disposal at the end-of-life. Aluminum alloys are very promising for structural applications in aerospace, military, and transportation industries due to their low density, high specific strength and resistance to corrosion, and especially regarding high energy cost. AA 6063 is an aluminum alloy, with copper as the primary alloying element.

2.0 literature review

P. Saha, D. Tarafdar, S.K. Pal, (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.

A. Shah, N.A. Mufti, D. (2010) The purpose of this paper is to investigate the effect of parameters on Cutting Rate (CR) for WEDM using aluminium alloy 6063 as workpiece and brass wire as electrode. This alloy is used in pipe, tube, ship and aerospace industries. Aluminium alloys are usually 20% to 30% lighter than steel alloys. It is seen that CR increases with increase in pulse on time and wire feed. CR decreases with increase in pulse off time and servo voltage.

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.

R. Khanna, H. Singh (2013) This paper discusses the influence of cutting variables such as feed, cutting speed and depth of cut at work-tool interface zone temperature and surface finish while machining aluminium alloy LM6 reinforced with Al_2O_3 metal matrix composites. Response surface methodology with central composite rotatable design matrix was employed to optimise and analyse the cutting variables.

3.0 METHODOLOGY

A wire EDM machine was utilized for test examination. This machine gives full scope of adaptability to the administrator in choosing parameters esteems. The hole amongst workpiece and wire was overflowed with a moving dielectric liquid 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 Voltage	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: milling process of AL6065 Material

The surface finish in machining can be measured directly. The TR Surface roughness tester shown in figure was used in this work. Three types of λ values can be given and the lambda represents distance to be moved over the finished surface by the stylus probe. Kirloskar Turnmaster-35 all geared lathe shown in figure was used in this research work. Distance between centres (max) is 800mm. Height of center is 175mm. The capacity of the motor is 3H.P/2.2KW.

Figure TR Surface Roughness Tester

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. Details of the material properties are given in Table.

Milling operation of AL6065 material

Table Chemical Composition

Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al

0.2-0.6	0.0-0.35	0.0-0.1	0.0-0.1	0.45-0.9	0.0-0.1	0.0-0.1	0.1max	Balance

Table Physical Properties

Property	Value
Density	2.70 kg/m3
Melting point	600°C
Modulus of elasticity	69.5 GPa
Electrical resistivity	0.035 * 10-6Ωm
Thermal conductivity	200W/mk
Thermal expansion	23.5*10-6 /k

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. Two tests were performed for each combination for turning operation resulting that 54 tests were conducted. Table presents the experimental details and their results.

Table Factors and Levels

Factor	Assignment	Levels		
		Level 1	Level 2	Level 3
Speed(N) m/min	A	100	150	200
Depth of cut(d)mm	B	0.25	0.5	1
Feed rate(f)mm/rev	C	0.05	0.075	0.1

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 experimental set up used in the present work. Experiments were conducted using CNC turning center manufactured by ACE machine tools. The cutting tool used is silicon carbide insert. The coolant used is SAE 40. The work-piece used in the present work is Aluminum 6061 in as cast condition having diameter 40 mm and length 150 mm.

Figure Experimental set up

The process parameters considered in the present study are shown in the Table. The levels of these parameters are chosen based on the pilot study conducted at various settings. Experiments were designed using Taguchi method to use the experimental resources optimally.

Table: Process Parameter and Their Levels

Factor/Level	1	2	3
Cutting Speed (m/min)	308	369	429
Feed (mm/rev)	0.05	0.1	0.15
Depth of Cut (mm)	1	1.5	2

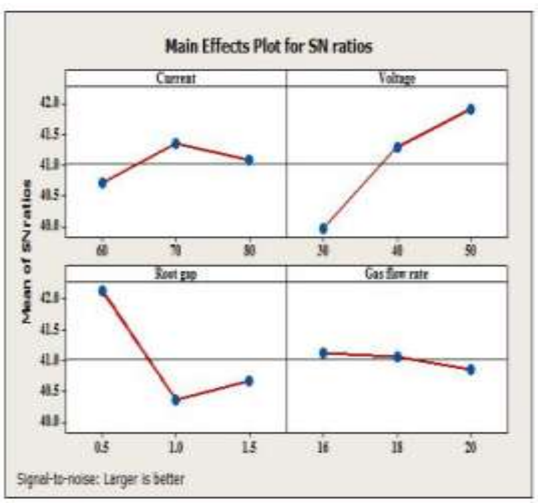
Experimental design is done with L9 Taguchi orthogonal array. Experiments were conducted at various levels of the process parameters as shown in the Table. Each trial is conducted in two types of test conditions. In the first condition machining is carried out without using coolant (called dry machining) and in second condition machining is carried by supplying the coolant while machining. The MRR of each experimental trial is measured by volume loss method (cm3 /min). Table also shows the corresponding MRR values obtained in each experimental condition as mentioned in the design. The experimental results were analyzed using analysis of variance (ANOVA) to estimate the relative effect of each process parameters.

Figure CNC lathe With Temperature Indicator

The levels of machining parameters to be studied and attribution of the levels are indicated in Table. In this experiment, the assignment of factors was carried out using MINITAB 15 Software. Using the Response Surface Design trial runs have been the conducted on CNC Lathe Machine for turning operations.

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

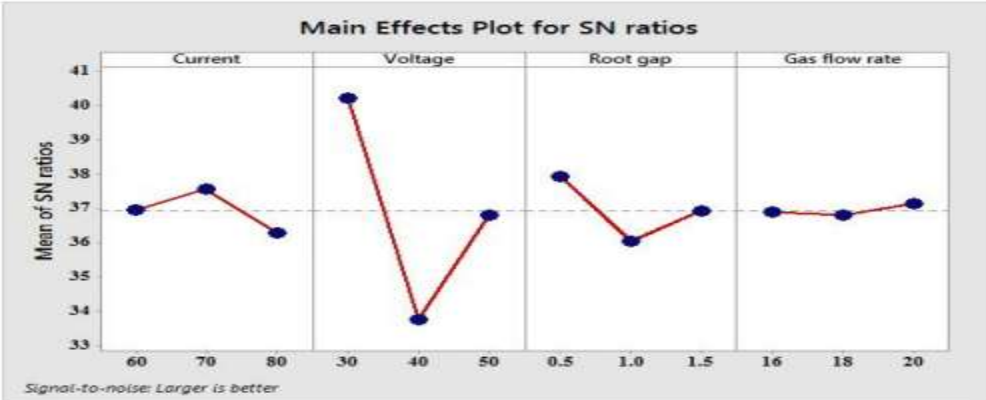
the goodness of the model; it determines how close the predicted values with the experimental values The values of R 2 are mentioned in Table, for the hardness value R-sq = 97.13 and R- sq (adj) = 96.27. This value indicates the goodness of designed model at states that designed model is valid for the 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

Analysis of Bend Strength

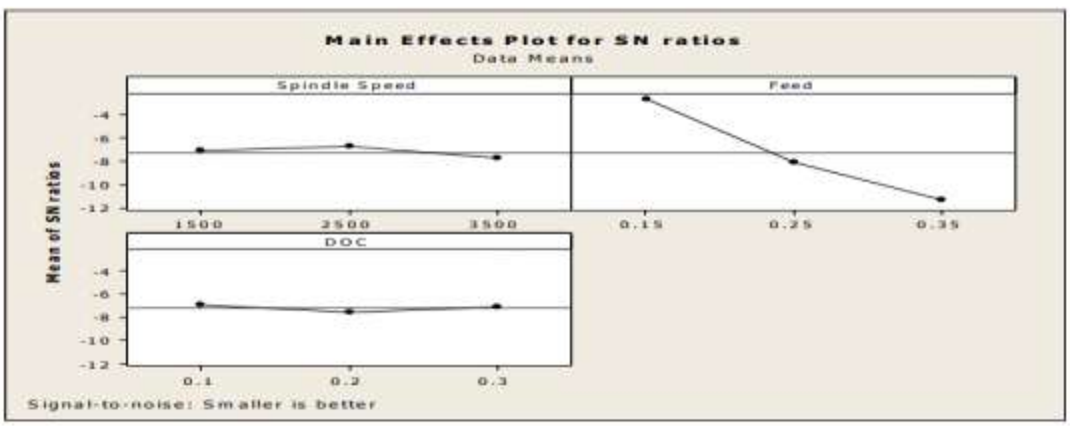
The bending test was carried out on different welded specimens. The mean plot graph is presented in figure and the response table is presented in table 6. In this investigation the most affecting factor was again voltage at its first level which indicates that when the voltage increases its strength reduces which is theoretically proved. As voltage is directly proportional to the arc gap when arc gap increases the voltage increases and in same way arc density reduces. The high voltage causes the welding defect known as lack of penetration and tends to reduce the welding strength. There is no cracks were found on the outer surface of the welded specimen which were welded under the low voltage condition.



Graph Main effects plot for SN ratios for strength property

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



Graph S/N Response Graphs for Surface Roughness

Fig. represents that there is a slight increase in the material removal rate when the cutting speed rises from 83 m/min to 125 m/min but there is a sharp rise in the same when cutting speed is increased from 125m/min to 167 m/min. Whereas fig. represents that there is a sharp effect of feed rate on MRR. When feed rate is increased from 0.06 mm/rev to 0.17 mm/rev the MRR increases but it slightly decreases when feed rate is further increased. Similarly in fig. effect of depth of cut on MRR is shown. There is a rise in the value of MRR with the increase in depth of cut.

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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