STUDY AND ANALYSIS OF EFFECTS OF VARIOUS CNC TURNING PARAMETERS ON SURFACE ROUGHNESS AND MATERIAL REMOVAL RATE

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Abstract: ***In the present study based on L9 array, the experiment is conducted on Aluminum 6351-T6 Alloy, Cylindrical rod of length 100 mm and diameter 24 mm on which the operation is done with selected parametric values, by using CNC turning using a carbide tool. The effects of various CNC Turning Parameters on surface roughness and material removal rate are studied. The effect of cutting conditions on the surface roughness is discussed. Analytically models have been created to predict surface roughness as function of cutting speed, feed rate and axial depth of cut.***

Index Terms – L9 array, Model, Cutting Conditions

I. INTRODUCTION

Surface quality is generally associated with surface roughness and can be determined by the roughness measurements. Surface roughness is determined by material irregularities obtained from various machining operations. To quantify this process response average surface roughness definition, often represented with Ra, is commonly used. Theoretically, Ra is the arithmetic average value of the gap between the nominal profile and the measured one. Ra is also an important factor is controlling machine performances. Surface roughness is influenced by tool geometry, feed, cutting conditions, tool wear, chatter. Turning can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using an automated lathe which does not. Today the most common type of such automation is computer numerical control, better known as CNC. (CNC is also commonly used with many other types of machining besides turning.). When turning, a piece of relatively rigid material (such as wood, metal, plastic, or stone) is rotated and cutting tool is traversed along 1, 2, or 3 axes of motion to produce precise diameters and depths. Turning can be either on the outside of the cylinder or on the inside (also known as boring) to produce tubular components to various geometries. Although now quite rare, early lathes could even be used to produce complex geometric figures, even the platonic solids; although since the advent of CNC it has become unusual to use non-computerized tool path control for this purpose.

Roughness plays an important role to determine how a real object interacts with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. Although roughness is usually undesirable, it is difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase exponentially its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application.

Asiltürk, I. et al [2011] studied Taquchi method to reduce surface roughness on hardened AISI 4140 (51HRC). The study focused on the investigation of the effects of cutting speed, feed rate and depth of cut on surface roughness. Feed rate was found to be the most effective parameter**.**

Dave, H.K. et al [2012] analyzed the cutting parameters for desired quality of surface. The study was focused on the optimization of cutting conditions for maximum material removal rate and less surface roughness. Form the studies depth of cut was found to be the effective parameter.

Hassan, K. et al [2012] investigated the effects of process parameters on Material Removal Rate (MRR) in turning of C34000. The optimization of MRR was done using twenty seven experimental runs based on L'27 orthogonal array of the Taguchi method. The optimum value of material removal rate was found to be 8.91.

Krishnamurthy,K. et al [2013] studied the performance analysis in turning process for Al6063 by using the Taquchi L 27 orthogonal array using carbide as tool material. He found that feed is the most important element for surface roughness. Also for material removal rate speed and feed are important parameters.

Sharma,P. et al [2013] studied the optimization of surface roughness and material removal rate by cutting speed, feed rate and depth of cut on AISI H 13 by using L 18 orthogonal array, ANOVA and GRA approach. The process was experimented on HMT STALLION – 100 HS CNC lathe machine and the optimum values were analyzed.

Bobbili, R. et al [2015] studied the comparative analysis of aluminum alloy 7017 and RHA steel for material removal rate and surface roughness.

Rao,R.K.[2015] experimented on En 19 material to analyze the effects of cutting parameters on surface roughness and material removal rate by using heat treatment and without the application of heat treatment.

Latif,A.A. et al [2017] studied the effects of cutting speed and feed rate for surface roughness and material removal rate. Mathematical formulation was used for calculating the material removal rate. Good surface finish and material removal rate were found with the increase in feed rate and cutting speed. Also a comparison was made between NOVIANO and conventional tool. NOVIANO cutting tool was found to be better.

Parthiban, A. [2017] et al used Response Surface Methodology to find the effect of feed and depth of cut on material removal rate and surface roughness. Mathematical modeling was also done for these parameters. He also predicted the optimization of process parameters.

Kumar.D. [2018] focused on applicability of CNC turning machine to perform operation on Aluminum Alloy 6351- T6 Material, which is having various advantages and applications. The study was resulted in arriving at factor level combinations corresponding to minimum value of surface roughness and maximum value of material removal rate.
Kumar.D. [2018] optimized the various parameters for material removal rate for Aluminum Alloy 6351- T6 Material which is widely used for construction of aircraft structures, such as wings and fuselages, more commonly in homebuilt aircraft than commercial or military aircraft.
Kumar, D. 2018. Focused on the parametric study of CNC turning process on aluminum alloy 6351-T6 using CNC milling machine. Based on initial study, L9 orthogonal array experiment plan was designed by considering Spindle speed, feed rate and depth of cut as main factors and surface roughness and material removal rate as responses.

II. TAGUCHI'S METHOD

Taguchi's philosophy developed by Genichi Taguchi, is an efficient tool for the designing of high quality manufacturing system. It is a method based on orthogonal array (OA) experiments which provides much-reduced variance for the experiments resulting optimum setting of process control parameters. Orthogonal array provides a set of well balanced experiment setting (with less number of experimental runs), and Taguchi's signal to noise ratios(S/N) which are logarithmic function of desired output; serves as objective function in the optimization process. This technique helps in data analysis and prediction of optimum results. In order to evaluate optimum parameter setting, Taguchi method uses a statistical measure of performance called as signal to noise ratio.

The S/N ratio takes both the mean and the variability into account. The S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). The ratio depends on the quality characteristics of the product/process to be optimized. The standard S/N ratios generally used are follows: - Nominal-is-Best (NB), Lower-the-Better (LB) and Higher-the-Better (HB).

III. MATERIAL PROPERTIES AND ITS APPLICATIONS

Aluminium 6351 T6 is a precipitation hardening aluminium alloy, containing magnesium, manganese silicon and zinc as its major alloying elements. It is generally available as tempered grade such as 6351 T6 it is one of the most commonly used alloys of aluminium for general purpose. The Properties are as follows.
Density : 2.6 to 2.8 grm/cc
Melting point : apprx 863 to 873 K
Modulus of elasticity: 70 to 80 GPa
Tensile strength : 250 GPa
Thermal conductivity: 176 w/m-k
Poisons ratio: 0.33

IV. EXPERIMENTAL DESIGN OF EXPERIMENT

Number of parameters = 4
Number of levels for each parameter= 3
Total degree of freedom (DOF) for three parameters = 4×(3-1) =8
Therefore minimum number of experiments = total DOF for the parameters +1
Minimum number of experiments = 8+1 = 9
So 3(3) L9 orthogonal array of Taguchi's was selected as shown in the table below

Experiment No.	***Column***			
	1	2	3	4
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**

Table 4.1 L9 orthogonal array of Taguchi's

V. MEASUREMENT OF RESPONSES

In this study Mitutoyo SURFTEST surface roughness measuring instrument was used for the surface roughness (R_a) measurement and the Material Removal Rate (MRR) is calculated by using the following mathematical equation with time consideration.

$MRR = \pi \times D_{avg} \times f \times d \times N$………………….. (eqn 5.1)

Here, $D_{avg} = (D_i - D_f) / 2$;

f = feed rate ;

d = depth of cut ;

N = cutting speed

VI. RESULTS AND DISCUSSION

The obtained experimental results of experiment for calculation of Surface Roughness are shown in the table No 4.5 below.

Expt. No.	Roughness for the Replicates (µm)			Mean R_a (µm)	S/N ratio
	1	**2**	**3**		
1	1.9615	1.805	2.0183	1.928	-5.71
2	1.9936	1.537	1.223	1.5847	-4.16
3	1.9335	1.7055	1.713	1.784	-3.41
4	0.8565	0.8865	0.8285	0.8571	1.33
5	4.098	4.0975	4.0415	4.079	-10.937
6	1.934	1.7915	1.899	1.8748	-5.46
7	1.673	0.928	0.7465	1.1158	-1.479
8	1.3805	1.107	1.1335	1.207	-1.679
9	6.642	6.1035	6.014	6.253	-15.9

Table no 6.1:Surface Roughness

The below depicted table shows ANOVA results of Ra for experiment

FACTOR	*D.O.F*	*Sum Of Square*	*Mean Square*	*F calculated*	*F tab*	*P%*
S	*2*	*2.120738874*	*1.0603694*			
F	*2*	*73.65303135*	*36.826516*	*52.09483749*		*31.59738155*
D	*2*	*6.681593922*	*3.340797*	*4.725895774*		*2.866424757*
NR	*2*	151.7644511	75.88222555	107.343096		*65.10742571*
ERROR	*1*	*0*	*0*			

Error	3	2.120738874	0.70691296			0.428767984
Total	9			164.8707423		100

Table 6.2: ANOVA results of Ra

VII. CONCLUSION

Based on experimental results, the optimum combination of factor is found as follows.
Speed should be kept at level 3, i.e. 750rpm
Feed should be kept at level 1, i.e. 0.15 mm/min
Depth of cut at level 1, i.e. 0.2 mm
Nose radius at level 1, I.e. 0.4mm

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