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Investigation of Machining Parameters for Turning Process

N. Baskar, Mohamed Nurul Islam A, Vigneshwer K, Judorohith S, *Antony Rosario S

Saranathan College of Engineering, Trichy, Tamil Nadu, India.

*Corresponding Author Email: antonyrosario764@gmail.com

Abstract: *Manufacturing industries mainly concentrates on how to minimize the cost of the products. The process planers have to prepare the process plan of the product based on the availability of the recourses. All the information is available in the plan including inspection and delivery date of the product. Based on the recommendation of the manufacturing and inspection methods, components are produced at affordable cost. Most of the research work concentrated on selection of machining parameters using optimization techniques and also prove that the machining time / cost were minimized for the particular components / operations. In this work, tool nomenclature is to be considered for the investigation for selection of machining parameters. Work presents an experimental investigation of the influence of the three most important machining parameters of depth of cut, feed rate and spindle speed on surface roughness during turning of aluminium alloy. In this study, the design of experiment which is a powerful tool for experimental design is used to optimize the machining parameters for effective machining of the work piece. L_9 orthogonal array experimental design method as well as analysis of variance (ANOVA) is used to analyse the influence of machining parameters on MRR & Machining Time. Two different grade of aluminium alloy i.e. AL 6063 & AL 6068 were machined with input parameters of depth of cut and speed. The output parameters are MRR and machining time. Based on the results empirical equations are formed and optimized results are validation .The optimal results are recommended to manufacturing industries.*

Keywords: *Turning process, Aluminum Alloy, MRR, Machining Time.*

1. INTRODUCTION

The Turning is a machining process performed on a machine in which the cutting tool (non-rotary tool bit) follows a helix tool path by moving linearly along the work piece. Turning traditionally refers to the action of cutting external surfaces, whereas “boring” refers to the action of cutting internal surfaces (holes). Thus, the phrase “turning and boring” classifies several processes known as lathing. In the turning process, the tool normally moves with the main axis (z) while the work piece rotates. When configured with a diameter less than the actual diameter of the work piece, it cuts off the work piece’s “surface” and reduces its diameter. It can also run perpendicular to the central axis. This operation is typically used to remove material only from the flat face (facing operation) or to remove a specific portion from the total length (cut-off). the standard turning process forces, which can also be seen given the parallel direction of the cutting tool and the spindle’s velocity. There are a few things to consider when a good accuracy and surface finish are required. Good operating quality, clamping stability, and correct centre height is three of these important factors. It is assumed that the chip generated during turning slides on the tool’s rake face. As positive rake angles produce higher shear angles, cutting forces are reduced, and chips flow more easily, resulting in a better surface finish of the work piece materials in the turning process. when turning, the work piece is rotated, and a cutting tool is rotated along 1, 2, or 3 axes of motion to produce precise diameters and depths. The main purpose of turning is to reduce the diameter of the work piece to the required dimension. The turning can be done either outside or inside the cylinder to produce tubular components for various geometries. In the tuning operation, the diameter must be cut to size in two cuts: roughness and finishing. For the work piece to have the same diameter at both ends, the lathe’s centre must be aligned. The fig 1.2 shows machining process where a lathe is used to rotate the metal while a cutting tool move in a linear motion to remove metal along the diameter, create a cylindrical shape.

2. LITERATURE REVIEW

[1] Its discussed about the acoustic emission (AE) sensors, were used to monitor machining anomalies and predict surface roughness during the SPDT of optical-grade polymethyl methacrylate. Material removal energy theory was adopted to obtain typical AE signal diagrams under tough cutting conditions, thereby enabling real-time monitoring. 2] discussed the cutting parameter optimization is considered as an effective way for energy consumption saving. In the machining process, the tool wear of cutting tools varies with the rise of the number of work pieces, which has a significant effect on cutting parameters decisions. However, most of existing approaches are conducted for a single work piece, and cannot select the optimal cutting parameters based on the dynamic changes in tool wear. To this end, a reinforcement learning-based cutting parameter dynamic decision (RLCPDD) method is developed for each work piece adaptive to the change of tool wear. Specifically, the correlation between the energy consumption, cutting parameters, and tool wear is analysed,. [3] studied about the experimental investigations and are performed according to a D-optimal statistical design of experiments. For this, the machining parameters cutting speed, feed, depth of cut, as well as the flank wear land width are varied on four levels. Subsequent measurements of residual. [4] prepared nano fluids by incorporating silicon dioxide (SiO_2) nanoparticles into sunflower oil were used as cutting fluids for turning AISI 304 stainless steel. Dynamic viscosities and thermal conductivities of nano fluids prepared at two different concentrations (1% and 0.5% by volume) were measured at four different temperature conditions.**.** [5] studied about the machine learning and image processing methods in estimating the tool wear values when turning AA7075 aluminium alloy. In addition, the in-depth analysis of cutting tools at different parameters were examined with SEM and EDAX analysis.. [6] discussed about metal matrix composites (MMCs) and they are new-age materials because of their elevated strength-to-weight ratio and enhanced mechanical as well as tribological performances. However, machining of MMCs is always challenging because of the presence of hard ceramic particles which are abrasive in nature. The ultrasonic vibration-assisted stir-cast method is employed to fabricate Al-TiB_2 composite with four different wt% of TiB_2 particles. [7] studied about the hybrid concept of multi-criteria decision-making and it has been proposed with the help of a multi-objective genetic algorithm (GA) and combined compromise solution (CoCoSo) for the central composite design of the experiment. The input variables have been selected as pulse-on time, pulse-off time, peak current and voltage for the machining of Ni-based hard faced deposit. Peak current .[8] studied to optimize the cutting tool parameters such as cutting speed, feed rate and depth of cut that enables better performance of the tool, wherein the performance parameters are material removal rate, tool wear and surface. [9] evaluated the new hybrid improved differential evolution and Nelder-Mead (IDE-NM) is introduced for optimizing the multi-objective machining process during the turning operation under three modes of lubrication conditions. The fitness functions are the tangential cutting force, the surface roughness, and the cutting power. [10] investigated the application of high-frequency vibration- assisted technology and it can make it a machining method for processing optical glass materials. However, due to the lack of understanding of intermittent cutting characteristics, it is still a challenge to achieve a high-precision and crack-free freeform surface on hard-brittle glasses. Therefore, the freeform surfaces of optical glasses are processed by ultrasonic vibration-assisted slow tool servo.

3. SELECTION OF MATERIALS

Tool Materials: Tool material refers to the substance or material from which tools are made. It plays a crucial role in determining the tool's performance, durability, and suitability for specific applications High speed steel is a highly alloyed tool steel capable of maintaining hardness even at elevated temperature, these are so named primarily because of the ability to machine materials at high cutting speed; it has usually high resistance to softening at temperature up to 600°C.

Work Piece Materials: In this project, two different grades of aluminium alloys are used (AL 6063 & AL 6068) Alloy 6063 create an aesthetically pleasing, coloured finish for visual architectural and building applications. It is commonly uses for window frames, door frames, roofs, and sign frames. Aluminium 6068 is widely used for manufacturing aircraft structures, fuselages and wings. It is also extensively used in fabricating automobile parts such as wheel spacers.

TABLE 1.

PROPERTIES	UNIT	VALUE
Density	g/cm^3	2.72
Tensile Ultimate Strength	MPa	205
Hardness, Rockwell c	HRC	70
Tensile Yield Strength	MPa	214

TABLE 2.

Properties	Unit	Value
Density	g/cm^3	2.7
Tensile Ultimate Strength	MPa	241
Hardness, Rockwell c	HRC	50
Tensile yield	MPa	214

Design of Experiments: DOE is a formal mathematical method for systematically planning and conducting scientific studies that change experimental variables together in order to determine their effect of a given response. It makes controlled changes to input variables in order to gain maximum amounts of information on cause and effect relationships with a minimum sample size. Design–Expert is a statistical software package from Stat-Ease Inc. that is specifically dedicated to performing design of experiments (DOE). Design–Expert offers comparative tests, screening, characterization, optimization, robust parameter design, mixture designs and combined designs. Design–Expert provides test matrices for screening up to 50 factors. Statistical significance of these factors is established with Analysis of Variance (ANOVA). Graphical tools help identify the impact of each factor on the desired outcomes and reveal abnormalities in the data. Design– Expert offers test matrices for screening up to 50 factors. A power calculator helps establish the number of test runs needed. ANOVA is provided to establish statistical significance. Based on the validated predictive models, a numerical optimizer helps the user determine the ideal values for each of the factors in the experiment. Design–Expert provides 11 graphs in addition to text output to analyse the residuals. The software determines the main effects of each factor as well as the interactions between factors by varying the values of all factors in parallel. A Response Surface Model (RSM) can be used to map out a design space using a relatively small number of experiments. RSM provides an estimate for the value of responses for every possible combination of the factors by varying the values of all factors in parallel, making it possible to comprehend a multi- dimensional surface with non-linear shapes.
Optimization Technique: The optimization module searches for a combination of factor levels that simultaneously satisfy the criteria placed on each of the responses and factors. To include a response in the optimization criteria it must have a model fit through analysis or supplied via an equation only simulation. Factors are automatically included “in range”. Numerical optimization uses the models to search the factor space for the best trade-offs to achieve multiple goals. The optimization feature can be used to calculate the optimum operating parameters for a process. Experimental design and optimization are tools that are used to systematically examine different types of problems that arise within, e.g., research, development
Analysis of Variance: Analysis of variance (ANOVA) is a collection of statistical models and their associated procedures (such as "variation" among and between groups) used to analyse the differences among group means. ANOVA was developed by statistician and evolutionary biologist Ronald Fisher. In the ANOVA setting, the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are equal, and therefore generalizes the *t*-test to more than two groups. ANOVA, the dependent variable must be a continuous (interval or ratio) level of measurement. ANOVA is useful for comparing (testing) three or more means (groups or variables) for statistical significance. It is conceptually similar to multiple two- sample t-tests, but is more conservative (results in less type I error) and is therefore suited to a wide range of practical problems. The systematic factors have a statistical influence on the given data set, while the random factors
Selection of Parameters: Turning is the process which has high metal removal rate and good surface finish. So turning is employed in most of the industries. The turning process is performed on the conventional light duty lathe. The selection of input process parameters plays crucial role for attaining high metal removal rate and good surface finish. Based on the customer requirements and machine specifications, the important turning process parameters influencing the metal removal rate, surface roughness, temperature and machining time is selected. For the optimisation of the single point cutting tool, the following parameters have been considered. All the experiments were conducted based on the L_9 orthogonal array recommended by the design of experiments and it is presented in Table 3.

TABLE 3. Factorial Design of Experiments for Input Parameters

Experiment Number	Input Parameters		
	Spindle Speed rpm	Feed Rate (mm/rev)	Depth Of Cut mm
1	290	0.75	0.5
2	455	0.78	0.5
3	680	0.74	0.5
4	290	0.78	0.75
5	455	0.74	0.75
6	680	0.75	0.75
7	290	0.74	1
8	455	0.75	1
9	680	0.78	1

Material Removal Rate

Material Removal Rate (MRR) is the primary response variable while considering productivity. Volume of chips removed in 1 minute, and it is

$$\mathbf{MRR} = \frac{\left(\begin{array}{c}\text{Weight of the work piece}\\ \text{Before machining}\end{array}\right) - \left(\begin{array}{c}\text{Weight of the work piece}\\ \text{after machining}\end{array}\right)}{\text{Machining Time}}$$

4. RESULTS OF AI6063 AND AI6068

When the Al 6063 was machined the metal tends to produce discontinuous chip. The chips are more likely in the very small particles. The material removal rate is high when the depth of cut and the working speed is high i.e., 1mm and 680 rpm. The tool tip tends to heat abnormally and the tool tip sharpness also get reduced. Frequent tool sharpening is required for the tool. The surface finish of the material is good. Then the work piece turned 0.5mm and 290 rpm. Metal removal rate is low but machining time is high. In depth of cut is 0.75mm and speed is 455 in this case, we get optimum metal removal rate and machining time.

TABLE 4. Experimental Results of Al 6063

Input			**Output**			
				Metal Removal		
DOC	**Spindle Speed**	**Feed rate**	**Time**	**Weight Before M/C**	**Weight After M/C**	**MRR**
(mm)	**(rpm)**	**(mm/rev)**	**(min)**	**(g)**	**(g)**	**(g/min)**
0.5	290	0.75	0.46	269	260	19.5652
0.5	455	0.78	0.3	270	266	13.333
0.5	680	0.74	0.18	271	262	43.75
0.75	290	0.78	0.46	271	258	28.26
0.75	455	0.74	0.28	270	266	14.2857
0.75	680	0.75	0.16	271	264	50
1	290	0.74	0.48	269	260	18.75
1	455	0.75	0.28	271	262	34.6154
1	680	0.78	0.1	271	264	70

When the Al 6068 was machined the metal tends to produce discontinuous chip. The chips are more likely in the very small particles. The material removal rate is high when the depth of cut and the working speed is high i.e., 1mm and 680 rpm. The tool tip tends to heat abnormally and the tool tip sharpness also get reduced. Frequent tool sharpening is required for the tool. The surface finish of the material is good. Then the work piece turned 0.5mm and 290 rpm. Metal removal rate is low but machining time is high. In depth of cut is 0.75mm and speed is 455 in this case, we get optimum metal removal rate and machining time

TABLE 5. Experimental Results of Al 6068

Input			**Output**			
				Metal removal		
Doc	**Spindle speed**	**Feed rate**	**Time**	**Weight Before M/C**	**Weight After M/C**	**MRR**
(mm)	**(rpm)**	**(mm/rev)**	**(min)**	**(g)**	**(g)**	**(g/min)**
0.5	290	0.75	0.46	134.5	130	23.07
0.5	455	0.78	0.3	135	133	35.38
0.5	680	0.74	0.18	135.5	131	58.96
0.75	290	0.78	0.46	135.5	129	34.43
0.75	455	0.74	0.28	135	133	56.57
0.75	680	0.75	0.16	135.5	132	99
1	290	0.74	0.48	134.5	130	43.77
1	455	0.75	0.26	135.5	131	80.81
1	680	0.78	0.2	135.5	132	105.06

5. CONCLUSION

- The experiments are conducted by the proper selection of turning process parameters to obtain good quality of machining by using Taguchi Orthogonal Array.
- The basic turning process parameters such as Spindle Speed, Feed Rate and Depth of Cut will be selected and examined at three different levels.
- Spindle Speed plays a vital role in finishing the work piece.
- To study the effect of turning parameters on the Metal Removal Rate and Machining time.
- The optimized turning process parameters for machining time such as spindle speed of 290 rpm, feed rate of 0.78 mm/rev and depth of cut of 1 mm & the Machining Time is measured as 0.102 min.
- Optimized turning process parameters for Material Removal Rate such as spindle speed of 679.97 rpm, feed rate of 0.78 mm/rev and depth of cut of 1mm & the Material Removal Rate Calculated as 32.5066 g/min.
- The optimized turning process parameters for machining time such as spindle speed of 680 rpm, feed rate of 0.76 mm/rev and depth of cut of 0.98 mm & the Machining Time is measured as 0.1644 min.

The optimized turning process parameters for Material Removal Rate such as spindle speed of 680 rpm, feed rate of 0.76 mm/rev and depth of cut of 1mm & the Material Removal Rate Calculated as 105.06 g/min.

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