PARAMETRIC STUDY OF CNC TURNING PROCESS ON ALUMINUM ALLOY 6351-T6

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Abstract: *Al 6351 is widely used for construction of aircraft structures, such as wings and fuselages, more commonly in homebuilt aircraft than commercial or military aircraft. 2024 alloy is stronger but 6351 is more easily worked and remains resistance to corrosion even when abraded. In the present study the parametric study of CNC turning process on aluminum alloy 6351-T6 using CNC milling machine was successfully undertaken. 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.*

Index Terms – Orthogonal array experiment, Aluminum 6351, CNC Turning

I. INTRODUCTION

Quality plays an important role in today's manufacturing market, as it directly influences the degree of satisfaction of its customers. A major indication of surface quality on machined part is surface roughness. Typically selected cutting operations have limited capability of attaining surface roughness. However it is necessary to determine optimal cutting parameters in order to achieve minimal expenses or cost/production time. Researchers have applied different methods for prediction of optimal cutting parameters. 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. Su and Tong [1997] proposed methods based on the principal component analysis (PCA) to optimize the multi-response problem in the Taguchi method, but they did not include the total variance of responses because only components with Eigen values equal to or greater than one are considered. Kopac, J eta al [2002] researched the optimization of parameters for turning cold drawn steel bars, using spindle speed, cutting tool material, work piece condition, depth of cut, and cutting sequence(first or second cut); and surface roughness as a response parameter. Fung,C.P. and Kang,P.C. [2005] optimized the injection-molding process for friction properties of fiber-reinforced polybutylene terephthalate using Taguchi method and principal component analysis. Four controllable factors of the manufacturing process were studied at three levels each. Using Taguchi method the single-response optimization of friction property was undertaken. Principal component analysis was employed to correspond to multi-response cases, for transforming the correlated friction properties to a set of uncorrelated components and evaluating the principal components. The optimum combination of process factors and levels for multiple qualities, based on the first principal component, was determined first. The appropriate numbers of the principle components, and the influence of the number on the optimum process condition, were subsequently studied by extracting more than one principal component and integrating into a comprehensive index. Finally, the analysis of variance was used to find out the most influential injection-molding parameter for single and multiple. Taraman,K. [2007] used response surface methodology (RSM) for predicting the surface roughness of different materials. A family of mathematical models for the tool life, surface roughness and cutting forces were developed in terms of cutting speed, feed, and depth of cut. Hasegawa et al. conducted 34 factorial designs to conduct experiments, for the surface roughness prediction model. They found that the surface roughness increased with an increase in cutting speed. Vishal S. Sharma [2008] et al optimized the surface roughness of aluminum by CNC turning process. In this study, machining variables such as cutting forces and surface roughness are measured during turning at different cutting parameters such as approaching angle, speed, feed and depth of cut. The data obtained by experimentation is analyzed and used to construct model using neural networks. The model obtained is then tested with the experimental data and results are indicated. Abdullah Naveen Sait [2010] presented an Optimization of Machining Parameters of Aluminium 6061 using Evolutionary Techniques. This work is an attempt to optimize the machining parameters of GFRP pipes by evolutionary techniques. GFRP pipes made by both hand layup as well as filament wound process are considered. Experiments were conducted based on Taguchi's technique and a combined objective is formed based on assumed weight age for individual parameters to minimize surface roughness, machining force and tool wear. In this paper the experimentally collected data are optimized through Particle Swarm Optimization (PSO) and Genetic Algorithm (GA). The results are analyzed and also compared with the traditional optimization technique. Palanivel, R. Et al [2013] studied an algorithm to develop a mathematical model for finding and optimizing the parameters of dissimilar aluminum alloy (AA6351 T6-AA5083 H111) joints by using the friction stir welding elements such as tool pin profile, tool rotational speed welding speed and axial force. Fusion welding is having low weld ability for aluminium alloys. The faster and reliable approach for aluminium alloy joints is by using friction stir welding. The quality of a weld joint is stalwartly influenced by process parameter used during welding. The effects of the FSW process parameters on the ultimate tensile strength (UTS) of friction welded dissimilar joints were discussed. Optimization was carried out to maximize the UTS using response surface methodology (RSM) and the identified optimum FSW welding parameters were reported. Patel, M.C et al [2014] suggested that among the various non traditional processes abrasive water jet machining is one of the most widely used. It is capable of machining geometrically complex and hard material components, that are precise and difficult-to machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold making industries, aerospace, and aeronautics industries. In present study, Experimental investigations were conducted to assess the influence of Process parameters like Orifice diameter (mm), Traverse speed (mm/min), Abrasive mass flow rate (gm/min) and Stand of distance (mm) on Surface Roughness (Ra) and Kerf Taper angle (Degree) of Aluminum 6351 T6 material. Here, using garnet as an abrasive material. The approach was based on Full Factorial method and analysis of variance (ANOVA) and Regression Analysis to optimize the process parameters for effective machining. ANOVA was perfumed to obtain significant parameter impelling Taper Angle and Surface Roughness, which gives the percentage contribution of each process parameter under operating Condition. Abrasive mass flow rate is most Significant and Travelling Speed, standoff Distances are significant parameter in 0.20 mm and 0.25 mm Orifice Dia. The Regression analysis is used to evaluation the regression coefficient that minimize the error and also predictions from the developed regression models were compared with measured Taper Angle (Degree) and Surface Roughness (μm) values. Vishnu,V.et al [2015] The present paper outlines an experimental study to optimize the effects of cutting parameters on Surface Roughness of Aluminium Alloy 6351 by employing Taguchi techniques. This paper deals with optimization of the selected milling parameters, i.e. Cutting Speed, Feed rate, Depth of cut and Coolant flow. Taguchi orthogonal array is designed with three levels of milling parameters and different experiments are done using L9 (34) orthogonal array, containing four columns which represents four factors, and nine rows which represents nine experiments to be conducted and value of each parameter was obtained. The nine experiments are performed and surface roughness is calculated. The Signal to Noise Ratio (S/N) ratio of predicted value and verification test values are valid when compared with the optimum values. It is found that S/N ratio value of verification test is within the limits of the predicted value and the objective of the work is full filled. Patel,M.T. [2015] Aluminum alloy has a wide variety of applications in different industries. Aluminum is the most famous for the lighter weight, strength/weight ratio, and recyclability, and corrosion resistance, ease of joining, easy of casting, durability, ductility, conductivity, surface finish and formability. The Challenge of modern machining industries is to manufacture the low cost and produce high quality product in shorter period of time. It is necessary to change and improve existing technology and develop product with reasonable price. So, it is necessary to control the process parameters in any manufacturing practices. The typical process parameters for the CNC lathe machines are speed, feed, depth of cut, tool geometry, wet cutting, dry cutting, tool material, work material, etc. which affect desired output like material removal rate, surface roughness, power consumption, tool wear, vibration etc. Selections of the process parameters are also very important to achieve the desired performance characteristics. If selections of process parameters are not proper, will lead to poor quality and productivity. ANOVA approach helps to determine whether selections of process parameters are appropriate or not. Optimizations of machining parameters are also required to determine for given responding characteristics to obtain optimal result. Kumar.D. [2018] Predicting surface roughness value before machining parts on a CNC lathe is very important. Improving quality and reducing cost, is possible by choosing optimum cutting parameters, using predictive models not by trial and error method. Surface roughness is an important measure of product quality since it greatly influences the performance of the mechanical parts as well as the production cost optimization of machining parameters not only increases the utility for machining economics, but also the product quality increases to a great extent. The study is 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 has resulted in arriving at factor level combinations corresponding to minimum value of surface roughness and maximum value of material removal rate. Kumar.D. [2018] one of the major problems in industries is to cut down the manufacturing cost without sacrificing the quality of the components. As a consequence of this, modern sophisticated machine tools need optimization procedure for the selection of operating parameters such as the cutting speed, feed rate, depth of cut, and nose radius. In the present study Aluminum Alloy 6351- T6 Material is used and various parameters are analyzed for maximum value of material removal rate.

II. TAGUCHI'S PARAMETER DESIGN APPROACH

In parameter design there are two types of factors that effects a products functional characteristics: control factors and noise factors. Control factors are those factors which can be easily controlled such as material choice, cycle time or mould temperature in an injection moulding process. Noise factors are those factors which are difficult or impossible or too expensive to control. There are three types of mould factors: outer noise, inner noise and between product noise. Examples of each type of noise factors and controllable factors in product and process design are listed in Table No. 2.5.2. noise factors are primarily response for causing a product's performance to deviate from its target value. Hence parameter design seeks to identify settings of control factor which makes the product insensitive to variations in noise factors i.e., makes the product more robust, without actually eliminating the causes of variation.

III. ANALYSIS OF VARIANCE (ANOVA)

It is statistical method for making stimulus comparisons between two or more means; a statistical method that yields values that can be tested to determine whether a significant relation exists between variables.

STATISTICS- A branch of applied mathematics concerned with the collection and interpretation of quantitative and the use of probability theory to estimate population parameters.

MULTIVARAIATE ANALYSIS- A genetic form for the statistical technique used to analyse data from more than one variable.
The analysis of variance was used informally by researchers in 1980s using least square physics and psychology; researchers introduced a term for the operator-effect, the influence of a particular person on measurements, according to StefenSteiglers histories. Sir Ronald Fisher proposed a formal analysis of variance in 1918 article.
In statistics, analysis of variance (ANOVA) is a collection of statistical models, and their associated procedure, in which 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. Doing multiple two sample t-test would result in an increased chance of committing a type I error. For this reason ANOVA is useful in comparing two, three or more means. There are several types of ANOVA. Many statisticians based ANOVA on the design of experiment especially on the protocol that specifies the random assignment of treatment to subjects; the protocol's description of the assignment mechanism should include a specification of the structure of the treatment and of any blocking.

IV. SELECTION OF TURNING PARAMETERS AND LEVELS FOR EXPERIMENT

Based on the literature survey various parameters which influences surface quality and production rate are determined, those parameters are controllable and uncontrollable parameters, from which more influencing parameters are selected.

1. Spindle speed in rpm.
2. Feed rate in mm/min.

3. Depth of cut in mm.
4. Nose radius in mm.

The bellow table shows the selected parameter combination for preliminary experiment with the four factors and three levels.

Parameters/factors	**Levels**		
	1	**2**	**3**
Spindle speed(Rpm)	450	600	750
Feed rate(mm/min)	0.15	0.2	0.25
Depth of cut(mm)	0.2	0.4	0.6
Nose radius(mm)	0.4	0.8	1.2

Table no 4.1: selected values of four factors with three levels for experiment

V. RESULTS AND DISCUSSION

For Material Removal Rate (MRR)

From ANOVA, it is found that the Depth of Cut is the most influencing parameter on response MRR, which is then followed by Feed rate, Spindle Speed and Nose Radius and also the optimum combination of factor, is found as follows.

1. Speed should be kept at level 3, i.e. 750rpm
2. Feed should be kept at level 3, i.e. 0.25 mm/min
3. Depth of cut at level 1, i.e. 0.2 mm
4. Nose radius at level 3, I.e. 1.2mm

The below depicted table shows ANOVA results of MRR for experiment .

FACTOR	**D.O.F**	**Sum Of Squares**	**Mean Square**	**F calculated**	**F tab**	**P%**
S	**2**	**29.41398136**	**14.7069907**	**367.504369**		**9.480625464**
F	**2**	**29.73739262**	**14.8686963**	**371.5451362**		**9.584866405**
D	**2**	**251.0221842**	**125.511092**	**3136.323107**		**80.90871082**
NR	**2**	**0.12005564**	**0.06002782**			
ERROR	**1**	**2.67164E-12**	**2.6716E-12**			
Error	**3**	**0.12005564**	**0.04001855**	**1**		**0.025797314**
Total	**9**			**3876.372612**		**100**

Table 5.1: ANOVA results of MRR

VI. CONCLUSION

Based on experimental results, following conclusions are reached:

From ANOVA, it is found that the nose radius is the most influencing parameter on response R_a, which is then followed by Depth of Cut, feed rate and Spindle Speed

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