OPTIMIZATION OF PROCESS PARAMETERS FOR SURFACE ROUGHNESS OF AL6351-T6 ALLOY IN CNC DRY MACHINING

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Abstract - In this paper, Taguchi technique was used to analyze the effects of machining parameters on surface roughness (SR) and material removal rate (MRR) of Aluminum 6351-T6 alloy. The machining parameters i.e spindle speed, feed rate and depth of cut were selected in this study. L₂⁷ (3³) orthogonal array has been used to conduct machining experiments. The spindle speed of 1200 rpm, feed rate of 0.03mm/rev and depth of cut of 0.6mm machined surface obtained the better surface roughness value of 0.339µm. The dominant factor for influencing the machining parameter was spindle speed followed by feed rate and depth of cut in CNC dry turning of Aluminum alloy.

Keywords Aluminum Alloy, Cutting Parameters, Surface Roughness, MRR, Taguchi

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I. INTRODUCTION

Aluminum alloys are widely used in automobile, structural, aircraft, marine and defense applications due to their excellent properties such as low weight to high strength, harness, tensile strength and corrosive strength [1-2]. Nowadays, CNC turning is one of the most common method is used for turning of aluminum alloys in order to get good surface finish in shorter time with economical. In the CNC turning center the various cutting parameters, such as cutting speed, feed rate, depth of cut, tool angles are greatly influencing for material removal rate. The material properties, tool material, working condition, cutting fluid, tool condition are important parameters affecting the response characteristics like surface roughness, power consumption, vibration, geometric tolerance and tool wear. Selection of the right cutting parameter is an important factor for getting the responding characteristics. The surface quality of products is generally determined in terms of the measured surface roughness. Proper selection of these control factors is an important factor to produce components with good surface finish and high tolerance in least time. It is highly desirable that products with good surface quality to be manufactured in least time. In the last few decades, a lot of work has been carried out to improve the product quality and efficiency in machining. Still various aspects related to this study are yet to be explored [3-4]. H. M. Somashekara et. al. (2012) [5] have studied the effects of machining parameters on surface roughness of Aluminum alloy using uncoated carbide inserts. By using different statistical techniques, they optimized the process parameters for better responses. Cutting speed has greater influence on the surface roughness followed by feed and depth of cut. N. Prabhakar et. al. (2014) [6] have studied the influence of machining parameters on surface roughness and material removal rate on Al6253 alloy using CNC turner. The results revealed that the feed rate and depth of cut are the most significant factors on the material removal rate and surface finish. Silberschmidt et al., (2014) studied the effect of ultrasonically assisted turning of different material in order to improve the surface roughness of the alloys. The cutting forces has decreased considerable amount for improvement of surface finish of the material. Recently Mozammel Mia et al. (2018) [7] machined the high hardness
steel with minimum quantity lubrication for prediction of optimum cutting parameters in order to improve the surface quality of the steel. D. Das et al. (2018) [8] observed that the surface roughness of Al7075 based metal matrix composites were improved with the proper selection cutting parameters. The optimum parameters were spindle speed of 1210 rpm, feed of 0.04mm/rev and depth of cut 0.1 mm. R. Horvath and A. Dregelyi-Kiss, (2015) [9] machined two different Aluminum alloys namely AS12 eutectic alloy and AS17 hyper eutectic alloy with three different diamond tools namely poly crystalline synthetic diamond (PCD), chemical vapor deposition synthetic diamond (CVD) and mono crystalline synthetic diamond (MDC). The hyper eutectic alloy has better surface finish quality in compare with eutectic alloy. The main purpose of this research is to identify the optimum cutting parameters using Taguchi technique in order to improve the surface roughness of the material using CNC lathe in dry machining condition [10-11].

II. MATERIALS AND METHODS

Al6351-T6 alloy of diameter 30mm and length of 200mm were used as work material. The chemical composition of the work material is presented in the Table 1. Prior to machining by CNC turner all the workpieces were rough turning was done by conventional lathe to avoid unnecessary vibrations, dimensional inaccuracies and defects. Then the workpieces were fixed in the LL20TL3 CNC turner in between the centers. The CNC machining set up is shown in Fig.1 As per the design matrix of Taguchi technique all the 27 experiments were carried out. To measure the surface roughness of the machined surface Taylor Hobson Surtronic 3+ instrument attached with computer was used. The rough and finished work piece specimens are shown in Fig 2 (a) and (b) respectively. The cutting tool with carbide tip of CNMG 120408-THM-F was used for turning. The specification of Carbide tool is presented in Table 2. Their carbide cutting tool has superior properties such as high hardness at elevated temperature, wear resistance and lesser thermal expansion.

Table 1 Chemical composition of Al6351-T6 alloy

| Chemical composition (wt%) | Si  | Mg  | Mn  | Fe  | Zn  | Ti  | Cu  | Al  |
|----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| 0.7                        | 0.5 | 0.5 | 0.2 | 0.1 | 0.1 | 0.1 | Rest|

Figure. 1 CNC experimental set up
III. RESULTS AND DISCUSSIONS

From the literature it has been found that many machining parameters affect the surface roughness and metal removal rate of the material. The important machining parameters were identified as spindle speed, depth of cut and feed. The selected machining parameters values and their levels are presented in the Table 3. For surface roughness smaller the better means the mean of surface roughness should be small for good surface finish. The S/N ratio was obtained by using Taguchi method. The S/N ratio should always high for less variation. S/N ratio represents the amount of variation presents in the performance characteristic. The response variables were surface roughness (Ra) and it was to optimized by using MINITAB software. The experimental results and their S/N ratios during CNC turning of Aluminum alloy is given in Table 4. The main effect plots for S/N ratio and main effect plots for means are shown in Fig. 4 and Fig. 5 respectively. The surface finish has been improved with increase in spindle speed with combination of lower feed and depth of cut. With increase in feed and depth of cut at lower spindle speeds the surface finish of the machining surface was deteriorated. The metal removal rate was larger with increase in spindle speed, feed and depth of cut. However, the surface quality of the surface significantly decreased.

| Cutting Parameters | Units | Level 1 | Level 2 | Level 3 |
|--------------------|-------|---------|---------|---------|
| Speed              | rpm   | 800     | 1000    | 1200    |
| Feed               | mm/min| 0.03    | 0.06    | 0.09    |
| Depth of Cut       | mm    | 0.6     | 0.8     | 1.0     |

Table 2 Carbide tool specification

| ISO catalog number | ANSI catalog number | Grade | D (mm) | L10 (mm) | S (mm) | Rɛ (mm) | D1 (mm) |
|--------------------|---------------------|-------|--------|----------|--------|---------|---------|
| CNMG120408         | CNMG432             | THM-F | 12,70  | 12,90    | 4,76   | 0,8     | 5,16    |

Figure. 2 Work Piece (a) Rough turning (b) Finish turning
### Table 4 Experimental results and their S/N ratios during CNC turning of Aluminum alloy

| Speed (rpm) | Feed (mm/min) | Depth of Cut (mm) | SR₁ (µm) | SR₂ (µm) | SR₃ (µm) | Mean (µm) | S/N ratio (dB) | MRR (mm³/min) |
|-------------|---------------|-------------------|----------|----------|----------|------------|---------------|---------------|
| 800         | 0.03          | 0.6               | 0.192    | 0.425    | 0.253    | 0.29       | 10.27645941  | 671.7982      |
| 800         | 0.03          | 0.8               | 0.271    | 0.344    | 0.297    | 0.304      | 10.29984939  | 892.715       |
| 800         | 0.03          | 1                 | 0.478    | 0.326    | 0.408    | 0.404      | 7.770893967  | 1112.124      |
| 800         | 0.06          | 0.6               | 0.395    | 0.321    | 0.335    | 0.350333   | 9.074068326  | 1343.596      |
| 800         | 0.06          | 0.8               | 0.494    | 0.347    | 0.574    | 0.471667   | 6.358112241  | 1785.43       |
| 800         | 0.09          | 0.6               | 0.26     | 0.354    | 0.299    | 0.304333   | 10.26384224  | 2224.248      |
| 800         | 0.09          | 0.8               | 0.676    | 1.03     | 0.841    | 0.849      | 1.297659595  | 2015.395      |
| 800         | 0.09          | 1                 | 0.607    | 0.649    | 0.7      | 0.652      | 3.700300537  | 2678.145      |
| 800         | 0.09          | 1                 | 0.661    | 0.809    | 0.84     | 0.77       | 2.225726943  | 3336.371      |
| 1000        | 0.03          | 0.6               | 0.3      | 0.297    | 0.304    | 0.300333   | 10.44753341  | 839.7477      |
| 1000        | 0.03          | 0.8               | 0.321    | 0.334    | 0.328    | 0.327667   | 9.690213296  | 1115.894      |
| 1000        | 0.03          | 1                 | 0.35     | 0.324    | 0.342    | 0.338667   | 9.400076742  | 1390.155      |
| 1000        | 0.06          | 0.6               | 0.44     | 0.39     | 0.327    | 0.385667   | 8.213788789  | 1679.495      |
| 1000        | 0.06          | 0.8               | 0.439    | 0.398    | 0.769    | 0.535333   | 5.028463469  | 2231.787      |
| 1000        | 0.06          | 1                 | 0.381    | 0.293    | 0.471    | 0.381667   | 8.211659236  | 2780.309      |
| 1000        | 0.09          | 0.6               | 0.76     | 0.916    | 1.06     | 0.912      | 0.722437689  | 2519.243      |
| 1000        | 0.09          | 0.8               | 0.845    | 1.08     | 0.938    | 0.954333   | 0.361698467  | 3347.681      |
| 1000        | 0.09          | 1                 | 1.12     | 1.08     | 1.06     | 1.086667   | -           | 4170.464      |
| 1000        | 0.09          | 1                 | 1.12     | 1.08     | 1.06     | 1.086667   | -           | 4170.464      |
| 1200        | 0.03          | 0.6               | 0.345    | 0.326    | 0.347    | 0.339333   | 9.384093126  | 1007.697      |
| 1200        | 0.03          | 0.8               | 0.236    | 0.287    | 0.367    | 0.296667   | 10.41350126  | 1339.072      |
| 1200        | 0.03          | 1                 | 0.375    | 0.372    | 0.266    | 0.337667   | 9.33344906   | 1668.186      |
| 1200        | 0.06          | 0.6               | 0.274    | 0.389    | 0.287    | 0.316667   | 9.874917831  | 2015.395      |
| 1200        | 0.06          | 0.8               | 0.305    | 0.353    | 0.313    | 0.323667   | 9.779801319  | 2678.145      |
| 1200        | 0.06          | 1                 | 0.32     | 0.378    | 0.388    | 0.362      | 8.796147427  | 3336.371      |
| 1200        | 0.09          | 0.6               | 0.578    | 0.709    | 0.691    | 0.659333   | 3.584445908  | 3023.092      |
| 1200        | 0.09          | 0.8               | 0.651    | 0.811    | 0.76     | 0.740667   | 2.572429326  | 4017.217      |
| 1200        | 0.09          | 1                 | 0.717    | 0.953    | 0.686    | 0.785333   | 1.999949601  | 5004.557      |

**Figure 3** Main effects plots for S/N ratios
Figure 4 Main effects plot for means

Table 5 Response Table for S/N ratio of surface roughness

| Level | Speed  | Feed  | Depth of cut |
|-------|--------|-------|--------------|
| 1     | 6.807  | 9.668 | 6.986        |
| 2     | 5.706  | 8.400 | 6.467        |
| 3     | 7.304  | 1.749 | 6.364        |
| Delta | 1.599  | 7.920 | 0.622        |
| Rank  | 2      | 1     | 3            |

Table 6 Responses for Means

| Level | Speed  | Feed  | Depth of cut |
|-------|--------|-------|--------------|
| 1     | 0.4884 | 0.3265| 0.4892       |
| 2     | 0.5803 | 0.3813| 0.5118       |
| 3     | 0.4624 | 0.8233| 0.5300       |
| Delta | 0.1179 | 0.4968| 0.0409       |
| Rank  | 2      | 1     | 3            |

IV. CONCLUSIONS

In this study Al6351-T6 alloy were dry machined in CNC machine with three different cutting parameters with three levels as per Taguchi design matrix and analyzed the surface roughness and Metal Removal Rate (MRR). With higher spindle speed of 1200rpm, lower feed rate of 0.03mm/rev and lower depth of cut of 0.6mm machined surface contributed the better optimum surface finish value of 0.339µm. The maximum MRR was found at the workpiece machined at higher spindle speed of 1200rpm, higher feed rate of 0.09mm/rev and higher depth of cut value of 1.0mm.

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REFERENCES

[1] D. B. Miracle, “Metal matrix composites—From science to technological significance,” Composites Science and Technology, vol.65, pp.2526–2540, 2005.
[2] S. Das, “Development of aluminium alloy composites for engineering applications,” Transactions of Indian Institute of Metals, vol.57, pp.325-334, 2004.
[3] S.T. Newman, A. Nassehi, “Universal Manufacturing platform for CNC machining,” Annals of the CIRP, vol.56, pp.459-462, 2007.
[4] M.T. Patel, “Investigation of Effect of Process Parameters on Different Performance Parameters for Aluminum Alloy on CNC– Review”, JETIR, vol.2, 2015.
[5] H.M. Somashekara and N. Lakshmana Swamy, “Optimizing Surface Roughness In Turning Operation Using Taguchi Technique and ANOVA”, International Journal of Engineering Science and Technology, vol. 4, pp.1967-1973, 2012.
[6] N. Prabhakar, B. Sreenivasulu, U. Nagaraju, “Application of ANOVA and ANN Technique for Optimize Of CNC Machining Parameters”, International Journal of Innovations in Engineering Research and Technology, vol.1, pp.1-12, 2014.
[7] M. Mia, M.S. Morshed, Md. Kharshiduzzaman, M.H. Razi, Md R. Mostafa, S.M.S. Rahman, I. Ahmad, M.T. Hafiz, A.M. Kamal, “Prediction and optimization of surface roughness in minimum quantity coolant lubrication applied turning of high hardness steel,” Measurement, vol. 118, pp. 43–51, 2018.
[8] D. Das, R. Kumar Thakur, A.K. Chaubey, A.K. Sahoo, “Optimization of machining parameters and development of surface roughness models during turning Al-based metal matrix composite,” Materials Today: Proceedings, vol. 5, pp. 4431–4437, 2018.
[9] R. Horvath, A. Dregelyi-Kiss, “Analysis of surface roughness of aluminum alloys fine turned: United phenomenological models and multi-performance optimization,” Measurement, vol.65, pp.181–192, 2015.
[10] D. C. Montgomery, “Design and analysis of experiments,” New York, John Wiley, 1991.
[11] M.S. Ranganath, Vipin, R. S. Mishra, “Optimization of Process Parameters in Turning Operation of Aluminium (6061) with Cemented Carbide Inserts Using Taguchi Method and ANOVA”, International Journal of Advance Research and Innovation, vol.1, pp.13-21, 2013.