Optimization of Process Parameters in CNC Turning of Aluminum 7075Alloy Using L27 Array-Based Taguchi Method

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Abstract -The manufacturing sector wants to create a lot of goods in a short amount of time as the fourth industrial revolution approaches. Response surface design and the Taguchi L27 orthogonal array methodological paradigm are used in this work. Through the use of a Computer Numerical Control (CNC) machine, the process parameters for turning aluminum alloy 7075 are optimized in this work. The force of cutting, the machined surface roughness, and the rate of metal removal were all affected by the ideal parameters. In this experimental study, the turning of Aluminum 7075 alloy in a CNC machine is optimized in terms of speed (800, 1200, and 1600 rpm), feed (0.15, 0.20, and 0.25 mm/rev), and cutting depth (1.0, 1.5, and 2.0 mm).

Key word: Al7075; turning parameters; Taguchi method; L27 array; signal to noise ratio

I. INTRODUCTION

Industrial sectors are concentrating on high production at low cost in the current market rivalry. Manufacturing sectors in particular are focusing on producing a wide range of goods in batches. These days, composites are used more widely as building materials in the majority of the top industrial industries. The only option available for producing components with tighter tolerances is machining. In many technical domains, the second generation of hybrid composites serves as a superior substitute for a variety of materials. In particular, lighter, higher-strength aluminum (Al) matrix composites must be used in place of ferrous materials in mechanical components used in the automobile, aerospace, and locomotive sectors. In order to turn the composites into technical components, the machining procedure becomes crucial and is always completed [1]. Because the reinforcing particles in Metal Matrix Composites (MMCs) are rough and abrasive, MMCs are

difficult to manufacture. As a result, machinability investigations have grown in significance within the composites field [2]. The researchers have taken into account a wide range of factors, including the work piece's features, the geometry of the cutting tool, the metallurgical properties, and process variables including feed rate, depth of cut, and cutting speed. The three main output responses that were impacted were tool wear, surface roughness, and cutting zone temperature.

Using the Taguchi approach [3], the best output responses were found during the turning process, and the parameters and their levels were chosen. The methodological paradigm employed in the design and analysis of the trials was the Taguchi method. The authors presented a successful strategy for producing high-quality, reasonably priced product improvements [4]. Referencing many research studies is necessary in order to manage multiple performance parameters using the Taguchi method [5]. Numerous scholarly works provided comprehensive elucidations regarding the importance of implementing various constraints to turn through the Taguchi approach [6]. The fundamental information and characteristics of Al 7075, such as its chemical compositions, were clearly presented by an examination of laser micromachining on the material for optimization. A study that looked at machining on Al7075-T7351 through experiments noted that there was a strong physical relationship between surface roughness and chip thickness [11]. Three hybrid composites made of Al7075 material were the subject of an experimental investigation that employed the turning process and concentrated on the specifics of the cutting force for the different factors of cutting depth (D), rate of feed (F), and speed of cutting (N) [12]. Researchers explained how they prepared for experimentation by using an orthogonal array (L27) to propose Taguchi's method for determining critical parameters that have a significant impact on cutting force and surface roughness [13]. Using the Taguchi gray relational approach, they examined the turning process at speeds between 125 and 185 m/min, feed rates between 0.12 and 0.20 mm/min, Depth of Cut (DOC) between 0.5 and 0.8 mm, and cutting fluid ratios between 4.0% and 12.0%.

Researchers were able to determine the DOC, cutting speed, cutting fluid combination ratios, and feed rate based on this investigation. The DOC was discovered to have the greatest influencing effect of all the components [14].

In the Taguchi approach, an orthogonal array (L9) was used in an experimental investigation of tool life, cutting force, surface roughness, and responses by taking into account parameters, such as feed (F) and speed of cutting (N) with DOC. Their study, which demonstrated the characteristics of the parameter correlations as well as the outcome outcomes, skillfully employed the optimization technique [15]. Tool life was inspected using a turning

process with cutting speeds ranging from 135 to 285 m/min, feed rates ranging from 0.08 to 0.32 mm/min, and DOC ranging from 0.6 to 1.6 mm.

The Taguchi method's force of cutting with roughness on a machined surface was added for gray relational analysis. However, they projected the optimization values for the best production on the turning process and explained every step of their inquiry in detail. It is clear from their study [16] that the feed rate produces a higher contribution than the other factors taken into account. AISI (American Iron and Steel Institute)-1016 carbon steel material was converted using cubic boron nitride while taking a number of factors into account. The parameters included speed ranging from 360 to 1150 m/min, feed ranging from 0.05 to 0.13 mm/min, and DOC ranging from 0.5 to 1.0 mm from start to finish. To assess surface roughness, the Taguchi approach was used. They observed that the rate of feed, speed, and DOC accounted for 64% of the primary contributing order [17]. The turning of AISI 1045 steel under dry cutting conditions using the Taguchi technique was investigated. A range of machining parameters, including speed (160–620 m/min), feed (0.3–0.5 mm/min), and DOC (0.7–0.9 mm), were used. Using a method for the machined surface's roughness and the rate at which metal is manually removed, they had finished computing signal-to-noise ratios and produced a match through the experiment [18].

II. EXPERIMENTAL ARRANGEMENT AND METHODOLOGY

Aluminum alloy AA7075 with 24 mm diameter rods were procured; then, the pur- chased materials were visually tested regarding any cracks or damage on the surface of the materials. Each specimen was prepared with a length of 150 mm and diameter of 24 mm. There is no change in diameter for the raw materials, and only the length needed to be cut. So, the long raw material was cut as 150 mm length rods. There were more than 27 raw specimens, which were prepared from the purchased material for turning, as shown in Figure 1.

Figure 1. Raw materials of Aluminum alloy Al7075 rods in multiple numbers.

The turning operation was considered for this investigation. This turning can be done by various machines such as normal lathes, etc., but the greater accuracy can be obtained from CNC machine only [24]. So, in this investigation, turning operations are perfectly completed with the help of a FANUC Series 0i controlled CNC machine. Figure 2 shows the CNC machine chosen for the experiments and the corresponding most preferable specification of that CNC machine, including the model of the machine, the spindle power, and size of the chuck; the spindle bore dimensions are clearly mentioned in Table 1.

Figure 2. CNC machine used for the experimental investigation

Table 1. CNC machine specifications with parameter for turning process and responses for the experiment.

	Model	ATL 160		
CNC machine specifications (heavy-duty variant of std TL-160)	Chuck Size	165 m		
	Tail Stock	Hydraulic		
	Spindle Bore	25.5 mm		
	Spindle Power Control	3.5/5.5 KW FANUC Series 0i mate.		
Turning	Speed (N) in rpm	800	1200	1600
Process	Feed (F) in mm per rev	0.150	0.200	0.250
Parameters	Depth of cut (D) in mm	1.00	1.50	2.00
Responses	mm^3/min	MRR—Metal removal rate in		
		SR—Roughness on machined surface in μm CF—Force of cutting in N		

Table 1 also mentions the turning process parameters (N, F, and D) and three responses (MRR, SR, and CF) for investigational experiments. The raw material is turned by using a CNC machine as per the dimensions shown in Figure 3, i.e., 80 mm long, 16 mm diameter turned from the 24 mm diameter Al7075 rod. In the CNC turning process, the heat was generated in between the specimens and tool; that heat was carried away from both of them by applying coolant such as soluble oil.
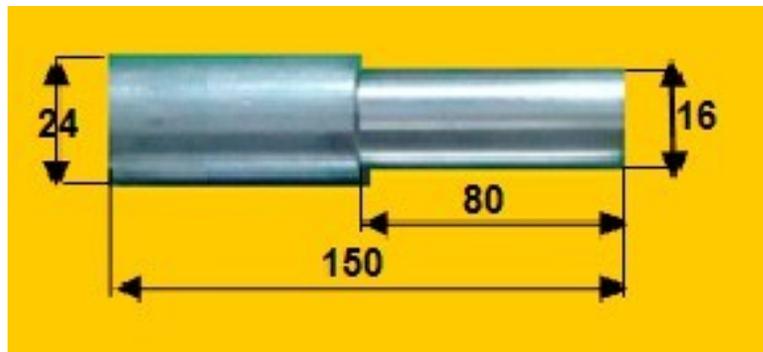
Figure 3. Turning operation: image after turning of Al7075 alloy with its dimensions.

Using an L27 orthogonal array, the twenty-seven numbers of specimens were ma- chined by applying 27 runs with correlations of parameters in CNC turning. The corre- sponding individual specimen responses such as cutting forces were measured with the help of a lathe tool dynamometer fixed on the machining setup in the CNC machine. The sensing elements have higher accuracy by using a strain gauge. The surface roughness was measured with the help of a surface roughness tester (Model: Mitutoyo SJ210) with a measuring range up to 160 microns. The evaluation parameters of this instrument such as Rx, Ry, Rz, and cut-off length were specified as 0.08, 0.25, 0.8, and 2.5 mm, and the sampling length of the instrument was specified as 0.08, 0.25, 0.8, and 2.5

mm. This instrument is used extremely often in industry with different sampling lengths (0.3 to 16.0 mm with 0.01 mm interval). All the responses compared chose optimum process parameters through the assistance of the Taguchi investigation method. Comparisons were completed as per the ideas shown in Table 2. In the turning process, MRR was preferred to be set as large (high), and a smaller amount of SR was favored for machining. Similarly, the minimum CF was set to be suitable for the operations [25].

Table 2. Summary of responses and its best conditions.

Comparison	Responses	Better/Best Conditions
1	Material Removal Rate (MRR)	Larger (High)
2	Surface Roughness (SR)	Smaller
3	Cutting Force (CF)	Smaller
4	Surface Roughness (SR) and Cutting Force (CF)	Smaller
5	Material Removal Rate (MRR), Roughness (SR) and Cutting Force (CF)	Nominal is best

III. ASSESSMENT OF RESULTS USING TAGUCHI ANÁLYSIS AND RSM

There were 27 specimens that were turned as per the dimensions mentioned in Figure 3 with the conditions N, F, and D, as shown in Table 3. After completing the tuning process, the specimens were fully cleaned, and oil was applied on the surface. Then, the experiment- tally measured responses of an individual specimen's results based on an L27 orthogonal array of process parameters were measured with the help Minitab 17 statistical analysis on the CNC machine, as mentioned in Table 3. Figure 4 shows the sample specimen after turning with respect to process parameters. It is to be noted that excess raw specimens were kept as balance.

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Specimen
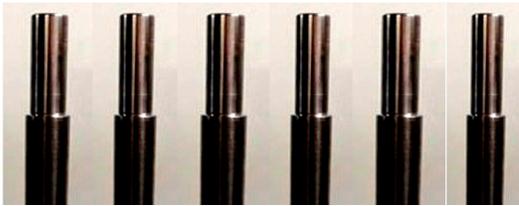
for the initial analysis, only one response—that is, MRR–was taken for the consid- eration. Table 4 clearly mentions the Taguchi analysis details of MRR versus speed (N), feed (F), and depth of cut (D). In addition, it also mentions the designated rank: i.e., rank one for feed, second rank for depth of cut, and third rank for speed. The corresponding main effects diagram regarding the ratio of signal to noise for the material removal rate is highlighted in Figure 5 under the larger is better condition [26]. The highest MRR is obtained at the conditions of 1600 rpm cutting speed, 0.25 mm per min of feed, and 2.0 mm of cutting depth as shown in Figure 5 with respect to the signal-to-noise (SN) ratio. The interaction diagram regarding the SN ratios of MRR is shown in Figure 6. It also provides the details of the individual factors such as N, F, and D as the separate diagrams of the combination with the response such as MRR.

IV. CONCLUSIONS

The proposed work takes into consideration the optimization of speed of cutting, feed, and cutting depth on the turning of Aluminum 7075 alloy through a CNC machine. When examining their effects on the metal removal rate, roughness of the machined surface, and force of cutting with the assist of L27 array, the Taguchi method produced substantial conclusions by taking into account the SN ratio, various surface diagrams, contour diagrams, and ranking positions. The maximum material removal rate was obtained at a speed of 1600 rpm, and a 0.25 mm/min feed with 2 mm cutting depth was preferred for the specimen number 27. Moreover, the least amount of surface roughness was reached through a speed of 1200 rpm and a 0.25 mm/min feed with 1 mm cutting depth for specimen 12. The lowest possible cutting force was accomplished at a speed of 1600 rpm and 0.25 mm/min feed with 2 mm cutting depth for specimen 27. Both parameters, i.e., CF and SR, achieved the smallest amount at 1600 rpm speed, 0.25 mm/min feed, and 2.0 mm depth of cut for specimen 27. By taking the nominal is best condition with respect to three responses, we attained 800 rpm speed, 0.15 mm/min feed and 2.0 mm depth of cut in specimen 7. Nonetheless, specimen 27 demonstrated a speed of 1600 rpm, and a 0.25

mm/min feed with 2 mm cutting depth were chosen as the optimum limitations for the greatest MRR and least amount of SR and CF.

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