Optimization of CNC machining process parameters for AA2014/WC composite

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Abstract: In this developed environment, most of the machineries and automobile parts are manufactured by using CNC machines. The working process for these requirements is common facing, turning, milling and so on. Of these surface roughness plays an important role. Since the strength and stability of the materials depends on the operation in which it undergoes on. The Taguchi method is adopted to decrease the work effort. This method replaces the work of turning to minimize the surface roughness (SR). The goal of this analysis is to optimize the effects of machining parameters of CNC turning machine for the Aluminium Alloy AA2014+12%WC with response of SR through using Taguchi approach.

Keywords: Machining, Taguchi analysis, ANOVA, Surface Roughness, Optimization.

1. Introduction

Surface roughness performs an essential role in many fields, as it is an significant factor in machining assessment. Turning is the fundamental process of removing metal from rotating cylindrical piece of work. Through this step, Taguchi method is adopted to decrease the roughness of the surface without the assistance of grinding operation. Taguchi technique is an effective tool for high-quality system design focused on orthogonal array tests that provide much reduced variance for experiments with optimal process control parameters environment. This provides an integrated easy and effective approach to finding the best selection of process designs for product quality, efficiency and computational cost. Taguchi approach uses a statistical performance metric termed as signal-to-noise ratio (S/N) that is the logarithmic function of the desired efficiency. The S/N ratio takes into account both variability and mean and describes average for Signal and standard deviation for Noise. The ratio relies on the product / process output characteristics to be improved. Lightweight materials
extensively used for automotive and aerospace applications because of low density and superior mechanical and physical properties [1-12].

1.1. CNC turning machine
Computer Numeric Powered computers are used in all form of production processes. Functions such as program storage, tool offset, tool compensation, software editing capability, different degree of computation, and the ability to send and receive data from a number of sources, even remote locations, can be easily achieved through on-board computers on a CNC machine. Multiple-part programs can be stored by the computer, retrieving them for specific parts as needed. Various cutting tools are used in CNC. High speed tool steel, cobalt-base alloys, cemented carbides, glass, polycrystalline cubic boron nitride and polycrystalline diamond are the types of cutting tool materials commonly used for machining operations.

1.2. Parameters that affects surface roughness
Whenever two machined materials make contact with each other, the consistency of the mating parts plays a vital role in the mating parts output and wear. The height, shape, structure and direction of these surface defects depend on various factors, such as: Speed, Feed, Nose radius, Surface roughness.

1.3. Comparison between grinding and turning operation
There are several factors that affect machine selection. When choosing a computer the following guidelines are to be made:
• Economic factors.
• Production rate and production cost per unit.
• Lower dismissal process.
• Setup time Minimum.
• Minimum time cycle.

1.4. Steps involved in Taguchi technique
Taguchi has suggested a standard practice for applying its system to automate any operation. The Taguchi approach utilizes research configuration orthogonal arrays to examine many variables with a limited number of tests. Its use of orthogonal arrays greatly limits the number of experimental structures to be explored.

Stage 1: Picking the proper process variables and finding of control factors.
Stage 2: Authorisation of each level of each factor.
Stage 3: Pick an orthogonal array experiment.
Stage 4: Accomplishment of matrix experiments through assigning control aspects to the column of OA.
Stage 5: Data evaluation to forecast optimum benefits and evaluate outcomes
Stage 6: Authentication and validation of the analyzed results.

1.5. Advantages over other methods
Taguchi technique is simple to learn and suited for any type of problem is that fewer experiments can be superimposed into more due to the orthogonal array.

1.6. Disadvantages
There may be two or more aspects combining to cause the problem, so that the problem may not be noticed.
• Five variables would require 50 tests, tested at three points.
• Maintaining the other variables constant while varying only one can be difficult or even impossible.
2. Experimental details
In this experimental work, the AA2014 aluminium alloy is considered as a primary alloy for the AMCs. The matrix and subordinate material (WC) is mixed in the proportion of 88% aluminium with 12% WC. The research methodology shall be as follows;

• Originally, the AA2014 will be melted after the insulation materials have been powdered.

• Both AA2014+WC are mixed and the molten mixture is kept at a temperature of 800°C.

• The mixture is stirred continuously at 300 rpm for 300 seconds.

• AA2014+12%WC mixture is poured into a different preheated mould.

• Multiple experiments have been carried out on the produced composite

After, the machining work was carried out on CNC turning centre employing high speed steel (HSS) drill bit. Table 1. reveal the process parameter for CMRR. Taguchi’s approach to design optimization involves a structured and efficient method for design engineers to determine near-optimum effectiveness and cost parameters.

The aim is to select the perfect combination of control parameters to ensure that the product or method is the most expansive in terms of noise factors. The parameters considered for machining were Spindle speed (N), Feed (f) and Nose radius (R). The control factors and parameters selected for machining are given in Table 1. The CNC Turning Centre used for the experiment is shown in figure 1.

| Control factors | Notations | Level 1 | Level 2 | Level 3 |
|-----------------|-----------|---------|---------|---------|
| Spindle Speed   | N         | 1000    | 1500    | 2000    |
| Feed            | F         | 0.15    | 0.20    | 0.25    |
| Nose radius     | R         | 0.40    | 0.80    | 1.20    |

Figure 1. CNC turning centre

3. Results and Discussion

3.1. Selection of orthogonal array
Experiments were planned in the orthogonal array of $L_9 (3^3)$, and their standard form is shown in Table 2. They conducted a set of nine experiments with four factors and three levels.
Table 2 Standard form for orthogonal array

| Exp. No | Control Factor |
|--------|----------------|
|        | N   | f | R |
| 1      | 1   | 1 | 1 |
| 2      | 1   | 2 | 2 |
| 3      | 1   | 3 | 3 |
| 4      | 2   | 1 | 2 |
| 5      | 2   | 2 | 3 |
| 6      | 2   | 3 | 1 |
| 7      | 3   | 1 | 3 |
| 8      | 3   | 2 | 1 |
| 9      | 3   | 3 | 2 |

The first test shows that the experiment will be done with a Spindle speed level at 1, and the level 2 feed and a level 3 nose radius. The remaining experiments have been carried out with the relevant factors and levels as shown in Table 3.

3.2. Experimental conditions
Parameters for machining allocated in an orthogonal array L₉(3⁴). Table 3. displays the experimental state for the control factor.

Table 3 Experimental Conditions

| Exp. No | Speed (N) | Feed (F) | Nose Radius (R) |
|---------|-----------|----------|-----------------|
| 1       | 1000      | 0.15     | 0.40            |
| 2       | 1000      | 0.20     | 0.80            |
| 3       | 1000      | 0.25     | 1.20            |
| 4       | 1500      | 0.15     | 0.80            |
| 5       | 1500      | 0.20     | 1.20            |
| 6       | 1500      | 0.25     | 0.40            |
| 7       | 2000      | 0.15     | 1.20            |
| 8       | 2000      | 0.20     | 0.40            |
| 9       | 2000      | 0.25     | 0.80            |

3.3. Signal to noise ratio
Signal to Noise ratio – smaller is better

\[ \frac{S}{N} = -10 \log \sum (\sigma^2 + R_{am}^2) \]

Where,
\( \sigma \) - Standard deviation of surface roughness
\( R_{am} \) - average value of surface roughness
3.4. Development of mathematical model
The calculated readings are feed into MINITAB 16 software to obtain the machining process's mathematical model. The Surface Roughness model predicted is given by surface roughness responses like Ra vs N, F, R.

Table 4. Details of experiments for surface roughness analysis

| Exp. No | Speed (N) | Feed (F) | Nose Radius (R) | Surface Roughness (Ra) |
|---------|-----------|----------|-----------------|------------------------|
| 1       | 1000      | 0.15     | 0.40            | 0.890                  |
| 2       | 1000      | 0.20     | 0.80            | 0.745                  |
| 3       | 1000      | 0.25     | 1.20            | 0.787                  |
| 4       | 1500      | 0.15     | 0.80            | 0.334                  |
| 5       | 1500      | 0.20     | 1.20            | 1.155                  |
| 6       | 1500      | 0.25     | 0.40            | 0.957                  |
| 7       | 2000      | 0.15     | 1.20            | 0.399                  |
| 8       | 2000      | 0.20     | 0.40            | 0.412                  |
| 9       | 2000      | 0.25     | 0.80            | 1.722                  |

3.5. Response of process parameters based on S/N ratio
The mean impacts for each process parameters are shown in Table 5.

Table 5 Response of process parameters

| Factors Levels | N   | f   | R   |
|----------------|-----|-----|-----|
| 1              | 1.8832 | 6.1726 | 3.0320 |
| 2              | 2.8851 | 3.0024 | 2.4538 |
| 3              | 3.6540 | -0.7528 | 2.9365 |
| Max – Min      | 1.7708 | 6.9254 | 0.5782 |
| Rank           | 2 | 1 | 3 |

3.6. Response curve for SN ratios
Answer curves are graphic descriptions of change in output characteristics with modification of the parameter stage of machining. Figure 2 shows a graph of the response for four factors and three levels.
3.7. Optimum machining parameters

The optimum set of machining parameters were found as given in the Table 6

| Spindle speed (N) | Feed (f) | Nose radius (R) |
|-------------------|----------|-----------------|
| 2000              | 0.15     | 0.40            |

4. Conclusion

In turning operation the influences of feed rate, nose radius and cutting speed on machined surface roughness were studied. The tests were carried out on AA2014/WC AMCs and the data collected were analyzed using Taguchi’s technique. It was observed that, in a small amount of experimentation, Taguchi’s orthogonal array provides a great amount of information. All four parameters contribute primarily to the response and all were considered. The optimum combination of machining parameters was found through the Taguchi technique. From the analysis the feed rate has 37.63 % of contributed and followed as nose radius is 3.704 % and cutting speed is 0.14 %. From the results, it is clear that feed rate is the most influencing parameter for minimum surface roughness which is followed by nose radius and cutting speed.

5. References

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