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Parameter Optimization Using CNC Lathe Machining

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Abstract: ***In today's manufacturing systems most of the time manufacturers, for retaining their position in the market competition, depends on manufacturing engineers and various production personnel in the industry. To get benefits of quick and effective setups while developments of manufacturing processes for new products. For the manufacturing challenges, the Taguchi parameter optimization method is a powerful and efficient tool for quality and performance output. This thesis discusses on the parameter optimization of CNC lathe machining for surface roughness using the Taguchi method, where surface roughness generated during machining. In the parameter optimization, the parameters are cutting speed, feed, and depth of cut. After selecting parameters turning on CNC lathe is to be done and selected orthogonal array and parameters used for the optimum set of combined controlled parameters for surface roughness. Into this combination of parameters selected for minimum surface roughness value and for the optimum combination of parameters by Taguchi design. Taguchi orthogonal array L9 for three parameters cutting speed, feed rate, and depth of cut with its combination surface roughness measured, analyzed and recorded by signal to noise ratios.***

Keywords: CNC Machining, Cutting Speed, Feed, Depth Of Cut, Taguchi, Minitab, L9, Orthogonal Array.

1. INTRODUCTION

For all machining process it is important to obtain accurate dimensions along with good surface quality and for achieving high production high MRR is important a machining process involves various parameters which can directly or indirectly affect surface roughness and material removal rate. Feed, speed, and depth of cut are very important parameter by varying which surface roughness and MRR can be affected. A good knowledge of optimizing the parameter can help in reducing the machining cost and improve product quality. Extensive study is done for optimization of the parameter so that better product is achieved. The current study is done on Taguchi method applied for most effective process parameters which are speed, Feed and depth of cut while machine mild steel workpiece with HSS tool. Three levels of the feed, three levels of speed, three values of the depth of cut, only one type of work material have been used to generate a total 9 readings in a single set.

Surface roughness remains the main indicator of machined component quality. A low surface roughness improves the properties, fatigue strength, corrosion resistance and aesthetic appeal of the product. A manufacturing engineer is expected to use his experience and use proper guidance to achieve the required surface finish. This must be done in a timely manner to avoid production delays, effectively to avoid defects, and to produce part of good quality. Therefore, in this situation, it is wise for the engineer or technician to use past experience to select parameters which will likely yield a surface roughness below that of the specified level by making an adjustment in the parameter as required.

A more methodical approach to setting parameters should be used to ensure that the operation meets the desired level of quality without sacrificing production time. Rather than just setting a very low feed rate to assure a low surface roughness, for example, an experimental method might determine that a faster feed rate, in combination with other parameter settings, would produce the desired surface roughness and will also not affect production rate.

2. PROBLEM STATEMENT

Work on our project was done to eliminate following problems observed

1) In machining on CNC lathe machine, the surface finish is not uniform & optimum.
2) Poor quality of workpieces.
3) While machining new material requirement of finding optimum parameter every time.

3. METHODOLOGY

TAGUCHI Methodology

The Taguchi method involves reducing the variation in a process through the robust design of experiments. The overall objective of the method is to produce high-quality product at low cost to the manufacturer. The Taguchi method was developed by Genichi Taguchi. He developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied. Instead of having to test all possible combinations of the factorial design, the Taguchi method tests pairs of combinations. This allows for the collection of the necessary data to determine which factors most affect the product quality with a minimum amount of experimentation, thus saving time and resources. The Taguchi method is best used when there is an intermediate number of Variables (3 to 50), few interactions between variables, and when only a few variables contribute significantly.

3.1 Process parameters

- **Cutting speed** - The rotational speed of the spindle and the workpiece in revolutions per minute (RPM). The spindle speed is equal to the cutting speed divided by the circumference of the workpiece where the cut is being made. In order to maintain a constant cutting speed, the spindle speed must vary based on the diameter of the cut. If the spindle speed is held constant, then the cutting speed will vary.
- **Feed rate** - The speed of the cutting tool's movement relative to the workpiece as the tool makes a cut. The feed rate is measured in millimeter per revolution (RPM)
- **Axial depth of cut** - The depth of the tool along the axis of the workpiece as it makes a cut, as in a facing operation.
- **The radial depth of cut** - The depth of the tool along the radius of the workpiece as it makes a cut, as in a turning or boring operation. A large radial depth of cut will require a low feed rate, or else it will result in a high load on the tool and reduce the tool life. Therefore, a feature is often machined in several steps as the tool moves over at the radial depth of cut.

3.2 Material selection for experiment

Literature survey reveals that material selection is not mentioned in many papers. Selection of material is a crucial step in optimization procedure. Material should be selected which has wide applications in industry and also not in focus or in less focus, so it has scope for further optimization. Mild .steel is well known and popular material.

3.4 Chemical composition Mild steel

Constituent	C	Si	Mn	P	S
% Composition	0.16-0.18%%	0.40%	0.70%	0.040% Max	0.040% Max

3.5Physical Properties of Mild Steel

Sr. No	Properties	Metric
1	Density	7.85 g/cc
2	Melting Point	2600˚c

3.6 Mechanical Properties of Mild steel

Max Stress- 400-560 n/mm2
Yield Stress - 300-440 n/mm2 Min 0.2%
Proof Stress- 280-420 n/mm2 Min
Elongation- 10-14% Min

3.7 Response parameters

- **Surface roughness (Ra)**

  Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if small, the surface is smooth. Surface roughness is denoted by SR in this report.

  In this work the surface roughness was measured by roughness tester. The surface tester is a shop–floor type surface-roughness measuring instrument, which traces the surface of various machined parts and calculates the surface roughness based on roughness standards, and displays the results in µm.

4 .DESIGN OF EXPERIMENT USING TAGUCHI METHOD

Classical experimental design methods are too complex and are not easy to use. A large number of experiments have to be carried out when the 86 number of process parameters increase. To solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments. Three superplastic forming parameters are considered as controlling factors. They are Pressure, Temperature and Time. Each parameter has three levels – namely low, medium and high, denoted by 1, 2 and 3 respectively.

According to the Taguchi method, if three parameters and 3 levels for each parameter L9 orthogonal array should be employed for the experimentation. Orthogonal Arrays (often referred to Taguchi Methods) are often employed in industrial experiments to study the effect of several control factors. Popularized by G. Taguchi. Other Taguchi contributions include:

• Efforts to push quality upstream into the engineering design process an orthogonal array is a type of experiment where the columns for the independent variables are “orthogonal” to one another.

Benefits:

1. Conclusions valid over the entire region spanned by the control factors and their settings
2. Large saving in the experimental effort
3. Analysis is easy to define an orthogonal array

One must identify:

1. Number of factors to be studied
2. Levels of each factor
3. The specific 2-factor interactions to be estimated
4. The special difficulties that would be encountered in running the experiment

When two-level fractional factorial designs are used, it begins to confound our interactions, and often lose the ability to obtain unconfused estimates of main and interaction effects. It was seen that if the generators are chosen carefully then knowledge of lower order Communications can be obtained under that assumption that higher order interactions are negligible. Orthogonal arrays are highly fractionated factorial designs. The information they provide is a function of two things

• The nature of the difficulty.
• Assumptions about the physical system.

Table 4.1 TAGUCHI L9 Runs of Experimental Design

Run	Cutting speed (N/mm^2)	Feed (watt)	Depth of cut(mm/min)
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

4.1 Methodology For Analysis of changing parameter

Review and study the literature survey

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Statement of hypothesis and specific objective for dissertation work

↓

Identify the input parameters

Cutting speed, feed and depth of cut

↓

Identify the output parameters

Surface roughness

↓

Experimental work setup

↓

Conduct the experiment

↓

Measurement of output variables

↓

Analyze the process by using TAGUCHI METHODOLOGY

↓

Optimize the process by TAGUCHI METHODOLOGY

↓

Validation of experiments

↓

Expected Outcome

5 ANALYSIS OF RESULTS

5.1 Signal to Noise (SN) Ratio

The parameters that influence the output can be categorized into two classes, namely controllable (or design) factors, and uncontrollable (or noise) factors. Controllable factors are those factors whose values can be set and easily adjusted by the designer. Uncontrollable factors are the sources of variation often associated with the operational environment.

The best settings of control factors as they influence the output parameters are determined through experiments. From the analysis point of view, there are three possible categories of the response characteristics explained below.

$\sum_{i=1}^{r} y^2 i$ = Summation of all response values under each trial

MSD = Mean square deviation

r is the number of tests in a trial (noise of repetitions regardless of noise levels)

J = Observed value of the response characteristic

y_o = nominal or target value of the results

The three different response characteristics are given by the following.

1) Higher is better. The SN for higher the better is given by:

$(SN)_{HB} = -10 \log (MSD_{HB})$ (Equation…..3.1)

Where MSD_{HB} =

$$= \frac{1}{r} \sum_{j=1}^{r} \frac{1}{y_j^1} \quad \text{(Equation ... 3.2)}$$

MSD_{HB} = Mean Square Deviation for higher-the-better response

2) Nominal is Better. The SN for nominal is better is:

$(SN)_{NB}$ = -10 log (MSD_{NB}) (Equation…..3.1)

Where MSD $_{HB}$ =

$$= \frac{1}{r}\sum_{j=1}^{r}(y_j - y_0)^2 \quad \text{(Equation ... 3.4)}$$

3) Lower is Better. In this design situation, response is the type of lower is better which is a logarithmic function based on the mean square deviation (MSD), given by

$(SN)_{LB}$ = -log 10 (MSD)

$$= 10 \log\left(\frac{1}{r}\sum_{j=1}^{r}(y^2)i\right) \quad \text{(Equation ....3.5)}$$

Where,

$$MSD_{LB} = \frac{1}{r}\sum_{j=1}^{r}(y_j^2)$$

SN Ratio for Response Characteristics

The parameters that influence the output can be categorized in two categories, controllable factors, and uncontrollable factors. The control factors that may contribute to reduced variation can be quickly identified by looking at the amount of variation present in the response. The uncontrollable factors are the sources of variation often associated with the operational environment. For this experimental work, response characteristics are given in the table

Table Response Characteristics

Response Name	**Response Type**
Surface Roughness	Lower is Better

4.7 Experimental Result

The optimum levels of parameters for minimizing the surface roughness were determined from the response table for Signal-to-Noise ratios. The best combination was obtained with:

- Cutting speed -1800
- Feed rate -0.1
- Depth of cut-0.4

Exp. No.	**Speed**	**Feed**	**Depth of cut**	**Surface roughness (R a)**
1	**1800**	**0.1**	**0.4**	**1.27**
2	1800	0.15	0.5	1.61
3	1800	0.20	0.6	2.70
4	2000	0.1	0.5	1.29
5	2000	0.15	0.6	2.02
6	2000	0.20	0.4	3.14
7	2200	0.1	0.6	2.12
8	2200	0.15	0.4	2.94
9	2200	0.20	0.5	3.13

CONCLUSION AND FUTURE SCOPE

Conclusion

Taguchi Design of Experiments was applied for turning parameters to obtain the optimal surface roughness. For our project, we have selected three turning parameters for optimization. Cutting speed, feed rate, and depth of cut. For each parameter, we selected three levels of various values.

Experiments were conducted using an L_9 orthogonal array. For each experiment, surface roughness was measured, recorded and analyzed using Taguchi S/N ratios. These ratios were calculated with consideration of performance characteristic: Lower-the-Better, as surface roughness is requested to below.

The optimum levels of parameters for minimizing the surface roughness were determined from the response table for Signal-to-Noise ratios.

To confirm the effectiveness of our optimization, we followed two ways:

- Confirmation experiment,
- Development of regression model with interactions between parameters.

Confirmation experiment revealed that Taguchi design cannot identify effectively the optimal parameters as the optimal turning parameters didn't lead to the minimal surface roughness. This result is due to the L_9 Taguchi orthogonal array, which doesn't include interactions between parameters.

Future scope

Material is widely used in industries for the different application e.g. uses for checkered plates, nuts & bolts, storage tanks, beams, channels, angles, hydraulic press rugged structures, washers, pipes & tubes, air receivers etc. and few worked on quality parameters like MRR, surface roughness for facing, power consumption, geometric tolerance like circularity, cylindricity, perpendicularity, etc. Taguchi approach help to determine optimal parameter condition for required output with help of lesser number of experiment (with help Orthogonal Array) & ANOVA approach help to determine which parameters are most significant.

An even better method can be used for parameter optimization wherein the values of the accuracy of surface finish which can be got for different material with the help of different variation in parameter can be up to a range of on hundredth of a micron.

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