Experimental Investigation And Optimization Of CNC Turning Of Stainless Steel 316

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Abstract

The study aimed to using the Taguchi method and Minitab software, optimize the CNC turning process settings for SS 316 to obtain improved surface roughness. Cutting speed, feed rate, and depth of cut were the three process parameters that were tested in nine tests using the Taguchi L9 orthogonal array. The response, surface roughness was measured using appropriate measuring instruments. The research outcomes were investigated by assessing the signal-to-noise (S/N) ratio to decide on the most suitable values for the process parameters. Further, the optimization of the process parameters was carried out using the Minitab software. The response optimizer tool in Minitab was utilized to find the optimal combination of process parameters that would yield the desired responses. The results of Minitab optimization validated the robustness of the optimization process because they were compatible with the Taguchi approach. The study provides valuable insights into the optimization of the CNC turning process for 316, which can be useful for industries involved in machining stainless steel components.

1. INTRODUCTION

Machining is a manufacturing process that shapes a workpiece by removing material with toolsand machines. To begin, the appropriate material must be chosen to withstand the forces and temperatures involved. Next, the workpiece is mounted onto a machine tool and set up for the specificmachining operation, including selecting the cutting tool, determining the feed rate and speed of the blade, and angling the tool with relation to the workpiece. During the process, the cutting tool removes material to create the desired shape, using a single-point or multi-point tool made from hard materials. Chips generated during cutting must be properly managed to avoid damage to the machine and ensure a high-quality finish. The finished workpiece may undergo additional processes, such as polishing or surface finishing, and can be used in various applications.

A type of machining known as CNC turning uses computer-controlled machinery to produce components with high levels of precision. A review of the available literature on CNC turning can offer insightful information on current developments, efficient working procedures, and industrial difficulties It may encompass a variety of topics, including CAD/CAM software integration, CNC turning process optimization, the machines utilized, cutting tools, materials processed, and cutting settings. A survey of this nature could enhance the effectiveness and caliber of CNC turning operations.

The provided text summarizes various research papers related to CNC turning of various materials. R. Ramasamy and S. Muthu Kumar's "Optimization of cutting parameters for CNC turning of SS316 using response surface methodology," R. Kumar and S. Kumar's "Effect of cutting fluids on the machinability of SS316 during CNC turning," V. Sharma and P. Singh's "Investigation of the effect of tool materials on the machinability of SS316 during CNC turning," and R. Ramasamy and S. Kumar's " These different papers focus on the optimization of cutting parameters, the effect of cutting fluids and tool materials on the machinability of SS316 and SS316L, and the improvement of surface quality during CNC turning CNC turning. The authors use various methodologies such as response surface methodology, grey relational analysis, and Taguchi method to model and optimize the cutting parameters. The experimental investigations provide valuable insights into the machining process of SS316 and SS316L, which are commonly used in industries such as aerospace and biomedical engineering. Several studies have investigated the optimization of cutting parameters during CNC turning of different materials, including AISI 304L stainless steel, and AISI 316L stainless steel. the investigations look at the effects of cutting parameters on machining performance indicators such surface roughness, material removal rate, and cutting force. Cutting parameters include feed rate, cutting speed and depth of cut. Different optimization techniques, such as Taguchi method, ANOVA, grey relational analysis, and response surface methodology, are used to optimize the cutting parameters for improved machining performance. The studies also investigate the effects of cutting fluids and cooling conditions on the machinability ofthe materials.

P. D. Dhaduk and R. D. Panseriya, (2020). In this study, the authors used the Taguchi method to optimizethe cutting parameters for CNC turning of AISI 316 stainless steel. The results showed that the optimalcombination of cutting parameters resulted in better surface finish and higher material removal rate. A.
K. Pradhan and R. N. Patel, (2020). This paper investigated the effect of Al2O3 and SiC reinforced Al6061 hybrid composite tool inserts on surface integrity and tool wear during CNC turning of AISI 316 stainless steel. In comparison to conventional tool inserts, the authors discovered that using hybrid composite tool inserts produced superior surface finishes and reduced tool wear.

2. MATERIALS AND METHODS

To extend the lifespan of cutting tools, machinists are paying more attention to hardening them, either with or without an enhanced hard coating. This means that the material used for a given machining job is crucial in establishing a successful outcome. Another way to reduce friction between the chip and tool is to alter the tool's geometry with a chip breaker which shortens the contact period. Then the little attention has been given on gaining an understanding of the influence of the work piece material in machining. The experimental investigations carried out on STAINLESS STEEL (SS 316) material was taken as work piece material.

Stainless Steel: (SS 316) SS 316 is a type of austenitic stainless steel that contains 16-18% chromium, 10-14% nickel, and 2-3% molybdenum. One of the most popular stainless steel types, it has exceptional mechanical qualities, excellent high-temperature strength, and excellent corrosion resistance. The presence of molybdenum in SS 316 its improves it in chloride settings by making it more resistant to pitting and crevice corrosion, making it ideal for use in marine and chemical processing industries. Additionally, the high nickel content in SS 316 provides excellent resistance to sulfurous acids and other reducing agents. Additionally, SS 316 is non-magnetic, making it the perfect material to employ in applications where magnetic qualities could be problematic. It is very adaptable and can be utilized in a variety of products, including as pharmaceuticals, medical implants, food processing equipment, and architectural applications. Standard forms of stainless steel 316 include sheets, plates, bars, pipes, and tubing. It is easy to machine, weld, and fabricate, making it a popular choice for manufacturers. SS 316 is an excellent material choice for uses requiring high corrosion resistance and favourable mechanical qualities, and high-temperature strength. It is widely available, easy to work with, and provides excellent value for its cost. Overall, the thermal expansion of SS 316 is quite modest, and it has good electrical and thermal conductivity.

Its non-magnetic properties make it useful in applications where magnetism is undesirable. Additionally, its high specific heat capacity allows it to absorb and release heat more efficiently, making it useful in applications where temperature control is important.

Tool Material: Tool materials are materials used for the fabrication of tools, which are used for cutting, shaping, or forming other materials. The selection of tool materials depends on the application, the material to be cut or formed, and the required tool life and performance. Drill bits, tool bits, milling cutters, etc. are examples of cutting tools used in machining, although knives and punches are examples of other cutting tools that are not made from cutting tool materials. Even at high temperatures during the procedure, the cutting tool's material must be tougher than the work piece's material. *TNMG – 160404:* TNMG 160404 is a specific type of carbide insert that is commonly used in turning operations. The designation TNMG 160404 represents the shape, size, and geometry of the insert. Here's a breakdown of what each part of the designation means. TNMG inserts are triangular in shape, with a cutting edge on each of the three sides. 16: This number represents the length of the insert, measured in millimeters. In the case of TNMG 160404, the insert is 16mm long. 04: This number represents the width of the insert, also measured in millimeters. In this case, the insert is 4mm wide. 04:This number represents the nose radius of the insert, also measured in millimeters. In this case, the inserthas a nose radius of 0.4mm. TNMG 160404 inserts are commonly used in turning operations that involve steel and other ferrous materials. The insert's geometry and chip breaker design make it ideal for roughing and finishing operations, and the carbide composition provides excellent wear resistance and toughness. Overall, TNMG 160404 carbide inserts are a versatile and reliable cutting tool used in a range of turning applications. Their geometry, chip breaker design, nose radius, and carbide composition make them ideal for roughing, finishing, and contouring operations in steel and other ferrous materials.

Introduction of DOE: Designed experiments or experimental design are other names for design of experiments (DOE). R. A. Fisher developed the Design of Experiments (DOE), a potent statistical method, in England in the 1920s to investigate the effects of several variables concurrently. Fisher sought to know how much sunlight, fertilizer, rain, and other factors are required to grow the finest crop in his early applications. Since then, the approach has undergone a great deal of refinement in the academic setting, but it has also inspired several applications on the factory floor.

L9 Orthogonal Array: In engineering and scientific research, the design of experiment (DOE) technique known as the L9 orthogonal array is frequently employed to examine the impact of numerous variables on a process or product. The L9 array is a specific type of orthogonal array that consists of 9 rows and 4 columns, where each row represents a unique combination of 4 factors and their corresponding levels.An L9 orthogonal array is a specific type of experimental design tool used in statistical analysis and quality control. It is used to systematically test a set of variables in order to determine which ones havethe greatest impact on a specific outcome or result. An orthogonal array is a matrix that is used to organize and analyze experimental data. In an L9 orthogonal array, there are 9 rows and a specific number of columns, depending on the number of variables being tested. Each row represents a different combination of variable settings, and the columns represent the individual variables being tested. The specific combination of settings for each row is determined based on a mathematical algorithm that ensures that each variable is tested an equal number of times and that the results are statistically significant. The L9 orthogonal array is a specific type of orthogonal array that is used when there are 3variables being tested, each with 3 possible settings. The first column displays the value of the first variable, the second column displays the value of the second variable, and the third column displays the value of the third variable. The settings for each variable are denoted by the numbers 1, 2, and 3. Each row of the L9 orthogonal array represents a different combination of variable settings, with no two rows having the same combination of settings. The purpose of using an L9 orthogonal array is to identify which variables have the greatestimpact on the outcome being tested. By systematically testing each variable at different settings, it is possible to identify which settings have the greatest impact on the outcome. The results can then be analyzed statistically to determine which variables are most important and to develop a model that canbe used to predict future outcomes based on different variable settings.

Terminologies of L9 Orthogonal Array: L9 orthogonal array is a type of experimental design that is commonly used in the field of statistics and quality engineering. It is a matrix of 9 rows and 4 columns, with each cell representing a specific combination of factors or variables. The L9 orthogonal array is designed in such a way that it ensures that each level of each factor appears in the design equally many times. The terminologies associated with L9 orthogonal array are,

• Factors: Factors are the variables or inputs that are being studied in an experiment. In L9 orthogonalarray, there are four factors that are being studied.

• Levels: Levels are the values or settings of the factors that are being studied. Each factor in L9orthogonal array has three levels, denoted by 1, 2, and 3.

• Runs: A run is a specific combination of factor levels in an experiment. In L9 orthogonal array, thereare 9 runs, each representing a unique combination of factor levels.

• Main effects: Main effects describe how each factor affects the response variable without reference to other factors. In L9 orthogonal array, there are four main effects, one for each factor. • Interactions:

Interactions refer to the combined effect of two or more factors on the response variable. In L9 orthogonal array, there are six possible two-factor interactions.

• Response variable: The response variable is the output or outcome of an experiment. It is the variable that is being measured or observed in response to changes in the input variables or factors. In L9 orthogonal array, the response variable is typically measured for each of the 9 runs.

• Orthogonality: Orthogonality refers to the property of the experimental design where the effects of each factor are independent of the effects of other factors. In L9 orthogonal array, the design is orthogonal, meaning that each factor is studied in combination with every other factor an equal numberof times.

L9 orthogonal array, in general, is a valuable tool for carrying out tests with various components and levels while requiring the fewest number of experimental runs. To optimize processes and raise the caliber of products, it is frequently utilized in quality engineering, product design, and manufacturing.

3. EXPERIMENTAL WORK

On a CNC machine, experiments were run by adjusting the spindle speed (N), feed rate (f), and depth of cut (d). Table 1 lists the variables that can be controlled along with their levels. Additional turning characteristics such tool geometry, work piece, and coolant (dry turning) were maintained. Due to the involvement of three turning parameters with three distinct ranges in this work, Taguchi L9 has been used. A high carbon and high chromium steel called TNMG 160404 was used for the experiment. This metal offers better resistance to heavy pressure, wear and abrasion. These characteristics make TNMG 160404 an excellent choice for die work on large production runs. It is basically oil-hardened steel. It is successfully used for making punches and dies on fairly thick (up to 1/4 inch thick) material. The process parameter values include feed (0.05-0.1) mm/rev, speed (750-1250) rpm, and depth of cut (0.1-0.3) mm.

L9 Orthogonal Array:

Specimen NO	Depth of cut	Speed	Feed	Surface Finish
1	1	1	1	0.545
2	1	2	2	0.534
3	1	3	3	0.961
4	2	1	2	0.407
5	2	2	3	1.326
6	2	3	1	1.590
7	3	1	3	0.951
8	3	2	1	0.758
9	3	3	2	0.915

Surface Roughness: A number of factors, such as the manufacturing process, wear and tear, and environmental factors like exposure to heat or moisture, can lead to surface roughness. For example, machining operations such as milling or grinding can leave behind tool marks and other surface imperfections that can impact the performance of the finished product.

4. RESULTS AND DISCUSSION

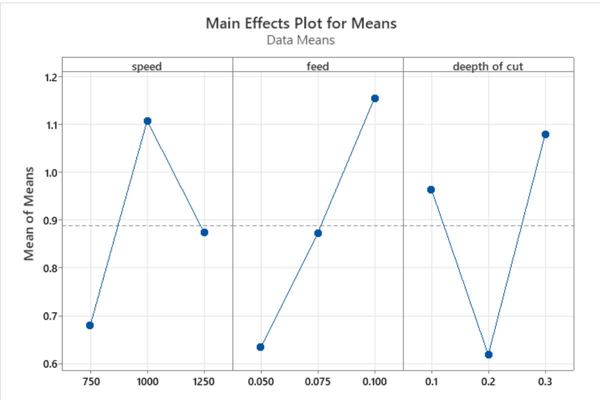
Effect of Turning Parameters: The Taguchi signal-to-noise (S/N) ratio technique was used to analyze how turning parameters affected surface roughness and material removal rate (MRR). The S/N ratio is an indicator of the experimental result quality. To minimize surface roughness, Equation (smaller-the-better) was used to evaluate the S/N ratio. The equations for determining the S/N ratio were; Smaller-the better $\lambda = -10 \log_{10} \left(\frac{1}{n}\sum_{i=1}^{n} R_i^2\right)$

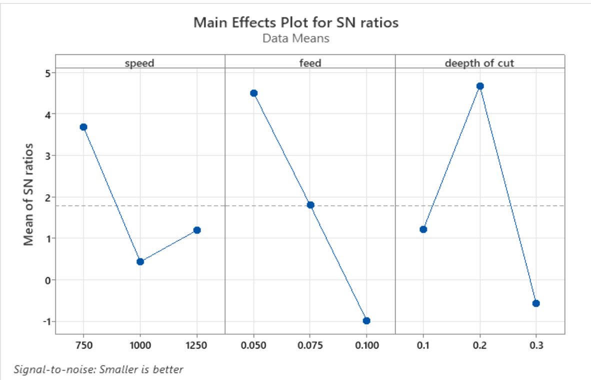
i = 1,2, …n

In the equations λ denotes for S/N ratio, n is the number of experimental runs, $R_i$is the measure of response for the i^{th}experimental run, and stands for the S/N ratio. The average S/N ratio of answers from different levels of the turning parameters shows their rank. The results confirm that turning depth of cut is shown to be the main determining factor for surface roughness and then the work speed and feed rate because it achieves the highest average S/N ratio for turning depth of cut (level 2 - 4.6763) than work speed (level 1 - 3.688) and feed rate (level 1 - 4.5055). It depicts that level 1 of work speed (750 rpm), level 1 of feed rate (0.050mm/rev) and level 2 of turning depth of cut (0.2mm) will produce minimum surface roughness. These results were validated experimentally.

S/N Ratio for Responses

Level	speed	feed	Depth of cut
1	3.6889	4.5055	1.2169
2	0.4431	1.8016	4.6763
3	1.2049	-0.9703	-0.5563
Delta	3.2458	5.4758	5.2326
Rank	3	1	2





The response graphs given in elucidate the variation of surface roughness with the turning parameters. The ideal machining conditions are shown in these figures, along with the relative effects of the turning parameter on responses (the gradient of the line). The gradient of the line connecting the different levels in the graphs describes the strength of each parameter's influence. It is noteworthy from the graph that the surface roughness decreases with decrease in work speed and feed rate.

5. CONCLUSION

In our study, we aimed to optimize the turning process of a widely used material in the manufacturing industry, SS316. We employed a 3-level 3-factor method by varying the speed, feed, and depth of cut input parameters to find the optimal combination that would minimize surface roughness, machining time and tool wear.

We utilized a strong tool to analyze the data and determine the best input parameter combination. the Minitab Taguchi technique, we were able to determine the most critical variables impacting the turning process, and we then used this information to select the ideal input settings. we were able to validate our findings and gain a better knowledge of the connections between input variables and output quality.

Our study's findings demonstrated that the 3-level 3-factor technique, when combined with the Minitab Taguchi method was a useful strategy for improving the turning of SS316. The production process is more effective and efficient thanks to the optimized turning process, which also cuts down on costs and time.

6. REFERENCE

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