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Parameters for Surface Grinding Austenitic Chromium Nickel Stainless Steel Sheet (AISI 304) Optimisation using Taguchi Method

Giri Vinod Madhav, Prof. Dengale Pravin Balasaheb

Department of Mechanical Engineering, Savitribai Phule Pune University, PUNE /SVCET, RAJURI, PUNE, Maharashtra, India

ABSTRACT: The mass production of thin, rotationally symmetrical components has established the surface grinding manufacturing method. Surface grinding is rarely used in limited-lot manufacturing because of the complicated setup that arises from this process's high sensitivity to a variety of kinematical, geometrical and dynamic effect boundary. The work piece's peripheral guidance and machining are done simultaneously, which is one of the process's key features. When finishing the machining of components that need smooth surfaces and exact tolerances, surface grinding is a necessary step. Grinding is a more expensive operation than other machining operations, hence it should only be used in the best circumstances. Among all the machining operations, grinding is still arguably the least understood despite being utilized extensively in industry. The suggested job makes use of the following input process parameters: depth of cut, federate and work speed. The main purposes of this work are to predict grinding behavior and achieve optimal operating process parameters. The main objectives of any machining operation are to maximize the Material Removal Rate (MRR) and minimize surface roughness. To maximize these values, regression analysis, ANOVA, and the Taguchi method are used.

KEYWORDS: Surface grinding, Taguchi method, ANOVA, depth of cut, feed rate, and work speed.

I. INTRODUCTION

Metal and other material components are shaped and finished by the material removal process called grinding. The precision and surface polish obtained by grinding can be up to ten times better than those obtained by milling or turning. In the grinding process, an abrasive material is usually a rotating wheel that is brought into controlled contact with a work surface. The abrasive granules that make up the grinding wheel are bound together by a binder. By acting as a cutting tool, these abrasive grains eliminate small material chips from the task. The greater resistance causes the abrasive grains to wear down and become dull, which weakens the binding between the grains. The dull bits split apart to reveal sharp grains that keep slicing. Among the prerequisites for effective grinding are:

Abrasive wheels that are resistant to heat and shock and have a tougher composition than the work

- The breakable grit. In other words, they have the ability to carefully fracture the majority of synthetic abrasives utilised in industry. Three quarters of all grinding processes involve the usage of aluminium oxide, which is mostly used to grind Silicon carbide & ferrous metals used in ceramics and other high-density materials, as well as softer, non-ferrous metals like cemented carbide, is the next material to be ground. Roughly 5 percent of grinding operations use super abrasives like diamond and cubic boron nitride. The best material to grind non-ferrous and non-metals with is diamond; hard ferrous materials are best processed with "CBN." The methods depend on the abrasive materials' grain size. Smaller grains yield a finer finish, whereas larger, coarser grains remove debris more quickly. These abrasive granules are bound together by binders such as: vitrified connections and a glass-like bond composed of fused clay.
- Rubber, shellac, and organic adhesives. Single-layer metal bonding techniques for extremely abrasive .

The primary industrial grinding operations are as follows, notwithstanding the fact that there are various methods of grinding:

- Surface grinding Process
- Internal grinding Process
- Center less grinding Process
- Cylindrical grinding Process

The work piece is stationary while the grind wheel spins quickly during surface grinding. External surfaces created by surface grinding might be curved, tapered, or straight. The wheel head which houses the drive motor and spindle, and the cross-slide which moves the wheel head to and from the work piece, are the fundamental parts of a surface grinder. The work piece is located, held, and driven by the wheel head. The finishing step is where the Surface Grinder is primarily utilised. During surface grinding, the work piece remains motionless while the grinding wheel rotates rapidly. Surface grinding can produce straight, tapered, or curved external surfaces. The required components of a surface grinder are the wheel head, which holds the drive motor and spindle, and the cross-slide, which moves the wheel head to and from the work piece. The wheel head locates, grips, and drives the workpiece. Using the Surface Grinder is mostly reserved for the final phase.. This process, which is more exact and accurate, uses a fixed, abrasive, rotating wheel that is held in place using a vise to shave or finish metallic surfaces. This is the area that moves under the abrasive wheel on a table or carriage. The material can be held stationary with the help of the grinder's magnetic table. These objects are drawn to iron, and you may turn them on and off with a lever on the front of the grinder. When compared to alternative methods of material removal, grinding is an expensive procedure that should only be used in ideal circumstances. Of all the machining operations, grinding is the one that is least understood despite being utilised extensively in industry. The primary operational characteristics that impact the output response parameters include tool wear, surface damage, surface roughness, and metal removal rate, among others. I Workpiece parameters include the chemical composition, mechanical characteristics, and manner of fracture. (ii) Process parameters, such as feed rate, dressing condition, depth of cut, and work speed; (iii) Wheel characteristics, such as form, diameter, binder, abrasive, grades, and grain size. (iv) Machine parameters that are static and dynamic Spindle system, table system, features, and so on. The proposed work makes use of the feed, depth of cut, and work speed input process characteristics. Rigid flanges are a popular application for alloy 304; this application calls for exact surface roughness due to use in chemical handling pipelines or equipment. For this reason, surface grinding needs to be at its best for this application. Thus, this application is being considered for this assignment. To simulate surface grinding processes, a software programme is employed that incorporates these different models. This work's predictions will be analysed by calibration using real data. Numerous factors are involved, including the depth of cut, feed rate, work piece composition, and work pace. Maximizing the Metal Removal Rate (MRR) and minimising surface roughness are the primary goals of this endeavour. The Taguchi method is used to optimise these parameters. For the ideal control settings that come from the analysis of Taguchi S/N ratios.

II. LITERATURE REVIEW

M. M. Salem, A. A. Ibrahim, S. S. Mohamed(2022) Surface grinding is one of the most extensively used procedures in industry for finishing materials. Different machining parameters have a great impact on a product's surface quality. While processing temperature increases and heat energy is generated, that may cause a few changes in the tool or work piece in chemical and physical properties. This will have an effect on the final product surface.

Hernadewita , Rochmad, I. , Hendra , Hermiyetti , Yuliani, E.N.S.(2019) Taguchi method is one of a design of experimental (DOE), by using statistical approach to optimize the process parameters and maintaining the minimum variability and also improve the quality of product. Based on data characterisation, Nominal is Best in Taguchi methods is suitable application in this study. Its describe the procedures and steps that occur in DOE to find an optimum quality parameter corresponding quality characterisation. Nominal is the best applied in milling process of pulp on the hydropulper with pulp freeness 650 Canadian Standard Freeness (CSF). The result is shown by orthogonal array, Signal-to-Noise (S/N) Ratio and analysis of variances (ANOVA)

Kamaldeep Singh, Dr. Beant Singh, Mandeep Kumar (2015) explains that grinding is an important procedure that rapidly eliminates material while preserving a high level of surface polish. To determine the ideal procedure parameters for abrasive-assisted surface grinding of AISI D3 tool steel, researchers utilize the Taguchi technique. Grain size, slurry concentration, table speed, wheel type, depth of cut, and L18 orthogonal array were the input machining variables used in the experiments on a horizontal spindle reciprocating table surface grinding machine. Following the experiment, an MRR calculator is used to measure the surface roughness using a surface roughness tester. ANOVA is used to analyse the data, and the S/N ratio is utilised to optimise them. This study demonstrates that A12 O3 grinding wheels are utilised for improved surface quality and c-BN grinding wheels are selected for higher MRR. The most important factor influencing MRR and surface roughness is depth of cut.

M. Aravind, Dr. S. Periyasamy(2014) claims that the Taguchi method and Response Surface Methodology (RSM) can be utilised to optimise the surface grinding process's parameters. The study takes into account three process

parameters: feed, depth of cut, and abrasive grain size on the grinding wheel. For grinding, a 100 mm by 10 mm by 10 mm square rod of AISI 1035 steel was considered. Surface roughness, or Ra and Rz, was selected as the output response. The Taguchi technique was used to examine the surface roughness features by selecting the L27 orthogonal array and analyzing S/N ratios. The Box-Behnken method was employed to optimise the response surface methodology. The surface grinder was put through thirteen tests. The ideal solution was found after entering the surface roughness parameters into the Design Expert program. Both techniques demonstrated that the cut depth and grain size of the wheel have a major impact on surface roughness. The surface roughness value is rarely dependent on the surface grinding feed. This study shown that in situations where input parameters are modifiable within the chosen ranges, Response Surface methodology performs better than Taguchi method. Experiments were conducted to verify the Response surface approach and the Taguchi-derived optimal solution. According to **Pawan Kumar, Anish Kumar, and Balinder Singh (2013)**, metal removal rate and surface cleanliness are critical performance factors that need to be taken into account during the grinding process. This work's primary goal is to investigate, through the use of three parameters—depth of cut, table speed, and grinding wheel speed—how abrasive instruments affect EN24 steel surfaces. The surface grinding device was used to conduct this study. In this work, wheel speed, table speed, and depth of cut were included as control parameters in empirical models for surface roughness and metal removal rate that were created using the response surface approach. Response surface methodology (RSM) was used in this work to establish the ideal machining parameters that would yield the lowest possible surface roughness and the fastest possible rate of metal removal during the surface grinding process. Wheel speed, table speed, and depth of cut all have a big impact on surface roughness and material removal rate. The Taguchi technique is a useful tool for developing and optimizing for quality for figuring out the ideal surface roughness for grinding operations, according to **Mustafa Kemal Kulekcy (2013)**. To examine the surface-roughness properties of AISI 1040 steel plates, an orthogonal array, a signal-to-noise (S/N) ratio, an analysis of variance (ANOVA), and EKR46K grinding wheels are utilized. This study not only provides the ideal surface roughness but also identifies the essential grinding factors that impact the efficacy of grinding operations. The efficiency of this strategy is validated by the supplied experimental data. The investigation's findings demonstrated that feed rate has less of an impact on surface roughness than wheel speed and depth of cut. This investigation demonstrated that wheel speed and cut depth were the primary factors influencing surface roughness. The surface roughness is less affected by the feed rate.

Janardhan and Gopala Krishna (2012) Mustafa Kemal Kulekcy (2013) states that the Taguchi technique is a helpful tool for developing and optimizing for quality in order to determine the appropriate surface roughness for grinding operations. An orthogonal array, a signal-to-noise (S/N) ratio, an analysis of variance (ANOVA), and EKR46K grinding wheels are used to investigate the surface-roughness characteristics of AISI 1040 steel plates. This study not only indicates the optimal surface roughness but also pinpoints the critical grinding variables that affect how well grinding operations work. The provided experimental data validates the effectiveness of this method. The results of the experiment showed that wheel speed and depth of cut have a greater influence on surface roughness than feed rate. This study showed that the main variables affecting surface roughness were wheel speed and cut depth. The feed rate has less of an impact on the surface roughness.

III.OBJECTIVE AND METHODOLOGY

A. Objective

B. Studying grinding behaviour and achieving ideal operating process parameters are the objectives of this endeavor. Applications that combine these various models are used to simulate surface grinding activities. The main objectives of any machining operation are to maximise material removal rate (MRR) and minimise surface roughness (Ra) . Therefore, in order to maximise these values, the Taguchi method is used.

C. Methodology

Objective of this experimental endeavor is to examine how depth of cut ,feed rate, and grinding speed affect Austenite stainless steel's (AISI 304 particularly) surface roughness (Ra).

C.Taguchi Method

The Taguchi approach uses a rigorous trial design to assist reduce process volatility. Producing Maximum-quality goods at the lowest possible cost to the maker is the primary goal of this process. Dr. Genichi Taguchi, a physician from Japan, invented and employs the Taguchi technique. Taguchi devised an experimentation technique to determine the effects of several factors on the mean and variation of a process performance characteristic that characterizes the processes' operation. Taguchi's proposed experimental design uses orthogonal arrays (OA) to arrange the Boundary that



influence processes and the levels at which they should fluctuate. The Taguchi method examines pairs of combinations or experimental Boundary as opposed to evaluating each and every possible combination and experiment. This saves time and money by enabling the gathering of the necessary data to identify the factors that substantially affect the product's quality with the least amount of experimentation. The Taguchi methodology is typically utilized when there are only a few significant variables, when there are interactions between components, or when there are between three and fifty variables. The Taguchi arrays can be obtained; deterministic algorithms can find huge arrays, while human approaches can find small arrays. Typically, arrays can be obtained via the internet. The number of tiers or states and the number of parameters determine which arrays are chosen. To find new parameter values that will optimize the performance characteristics, an analysis of variance will be applied to the data collected from the Taguchi design studies. ANOVA can be used to make a visual analysis of the array data by placing it on display. It is well recognized that in order for any production process to realize its maximum potential—both economically and technologically—optimal conditions must frequently be satisfied. The Taguchi method is among the most significant optimization strategies. With fewer simulation trials, the Taguchi technique provides a thorough grasp of both the individual and combined process parameters. An approach to designing experiments with unique application principles is the Taguchi methodology. This methodology or strategy makes it easier to explore or evaluate how different variables affect the required quality standards in the most cost-effective way possible. Determining the optimal combination of factors may be aided by knowing how various components affect the outcomes. Taguchi uses specifically created tables called "orthogonal arrays" (OA) while creating tests. A matrix of numbers arranged in rows and columns is called an orthogonal array. These tables make experiment design very straightforward and harmonic; only a few trial runs are needed to fully understand all parameters. Reductions in labor, expenses, and time are therefore possible. The generic signal-to-noise (S/N) ratio is used by the Taguchi method to quantify the current variation. The S/N ratios are employed to quantify the impact of noise on performance indicators. S/N ratios account for both the average response's proximity to the aim and the degree of variation in the response data. We translate the experimental results into a signal-to-noise (S/N) ratio. In order to identify the quality aspects that differ from the planned values, Taguchi suggests using the S/N ratio. When analyzing the S/N ratio, three types of quality standards are typically established: the better the smaller, the higher, and the better the nominal. Based on the S/N analysis, the S/N ratio is given for every process parameter level. The highest S/N ratio is associated with superior quality attributes. Thus, the process parameter level with the largest S/N ratio is the ideal level. Taguchi proposes utilizing the loss function to calculate the quality characteristic's divergence from the ideal value. The signal-to-noise (S/N) ratio is also constructed using the value of the overall loss function. Three categories are typically used to classify the quality characteristic in the S/N ratio study: larger, more nominal, and lower-the-best. Based on the S/N analysis, the S/N ratio is given for every process parameter level. A higher S/N ratio denotes a higher quality trait, independent of the category of the quality characteristic. Thus, the process parameter level with the largest S/N ratio is the ideal level. An extra statistical analysis of variance (ANOVA) is performed to determine the statistical significance of the process parameters. The ideal set of process parameters can then be estimated after that. The experiment is ultimately conducted to verify the ideal process parameters that the process parameter design identified.

D.Taguchi Method of Orthogonal Arrays

PARAMETERS-3

1. Rotational Speed- e.g. X, Y, Z.
2. Feed- e.g. S, Q, L.
3. Depth of cut- e.g. A, C, B.

Here there are total three levels for each parameter.

EXPERIMENT	ROTATIONAL SPEED	FEED	DEPTH OF CUT
1	X	S	A
2	X	Q	C
3	X	L	B
4	Y	S	C
5	Y	Q	B



6	Y	L	A
7	Z	S	B
8	Z	Q	A
9	Z	L	C

Table 1: Taguchi design of experiments according to L9 orthogonal array

Sr. No	Process Parameters	Range	Level 1	Level 2	Level 3
1	Rotational speed	400-1100 m/min	400	750	1100
2	Feed	3-15 m/min	3	9	15
3	Depth of cut	3-18 μ m	3	10.5	18

Table 2: Process Parameters with their values at corresponding levels.

IV. RESULT AND DISCUSSION

Surface Roughness experimental data following the grinding operation and the corresponding S/N ratio.

Sr. No.	Speed (rpm)	Feed (m/min)	DOC (μ m)	R_a (μ m)	SN Ratio
1	400	3	3	1.107	-0.8819
2	400	9	10.5	1.424	-3.0712
3	400	15	18	1.343	-2.5625
4	750	3	10.5	0.871	1.1986
5	750	9	18	1.469	-3.3414
6	750	15	3	1.385	-2.8280
7	1100	3	18	1.666	-4.4325
8	1100	9	3	1.770	-4.9584
9	1100	15	10.5	1.586	-4.0070

Table 3: Result table

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	2	13.436	13.436	6.723	5.01	0.168
Feed	2	9.386	9.386	4.698	3.59	0.233
Depth of cut	2	3.386	3.386	1.693	1.27	0.443



Residual Error	2	2.685	2.685	1.343		
Total	8	28.871				

Table 4: Analysis of Variance for SN ratios of Ra

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	2	0.3359	0.3359	0.1676	8.16	0.102
Feed	2	0.1788	0.1788	0.0894	4.15	0.188
Depth of cut	2	0.0607	0.0607	0.0305	1.49	0.404
Residual Error	2	0.0412	0.0412	0.0207		
Total	8	0.6168				

Table 5: Analysis of Variance for SN ratios of Mean

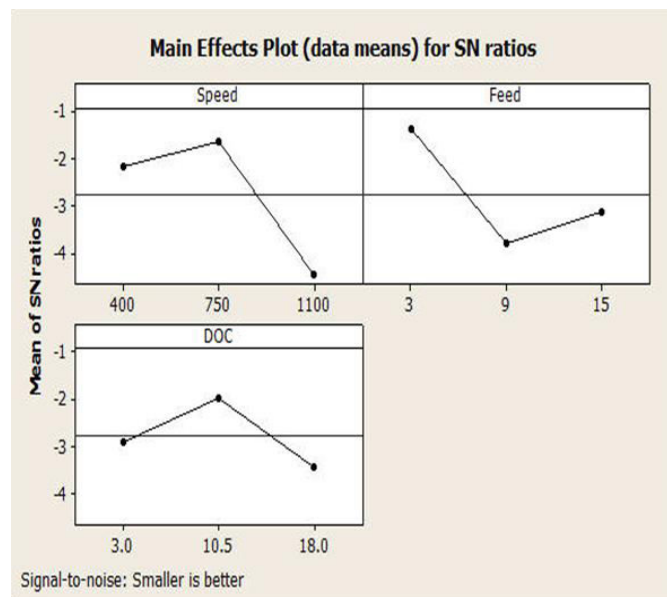


Figure 1. Main Effect Plot for SN Ratio

The surface finishes of austenitic stainless steel (AISI 304) after the experiment are mentioned below.

- In the surface grinding process, speed is one of the key determining factors of surface roughness. The optimal surface finish parameters for Austenitic stainless steel AISI 304 surface grinding are 750 m/min of speed, 3 m/min of feed, and 10.6 μm of depth of cut. These parameters are shown in Tables 3 and 4 as well as in Figure 4.
- Nonetheless, austenitic stainless steel (AISI 304) produces the best surface finish and has good machinability characteristics.
- Austenitic stainless steel has a low tendency to fracture and produces a superior surface polish.

V. CONCLUSION

Following a series of surface grinding studies, I draw the following conclusions:

- Austenitic stainless steel produces a good surface finish during surface grinding when the grinding process parameters are optimized.
- It is possible to attain close dimensional tolerance when surface grinding..
- In AISI 304 austenitic stainless steel, speed is crucial for producing a good surface finish. For example, 750 rpm cutting speed, 3 m/min, and 10.5 μm cutting depth are required.
- The problems of poor wheel loading, wheel burning, and chip breaking are resolved by austenitic stainless steel (AISI 304), which also has strong machinability qualities.
- Speed is a factor that influences surface roughness.
- The issues of inadequate chip breakage and machining distortion are resolved by surface grinding at its ideal parameters.

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