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# REVIEW ANALYSIS ON OPTIMIZATION OF CYLINDRICAL GRINDING PROCESS PARAMETERS BY USING TAGUCHI TECHNIQUE

Nesredin Chekole

Dr. Vivek Deshpande

## Abstract

*In grinding operation the selection of optimum process parameters is crucial. In this paper a review for the effect of various process parameters on cylindrical grinding operation is done for different materials. To achieve the objective of getting optimum MRR and surface finish at minimum possible machining cost and time different investigators used various input parameters like: work speed, wheel speed, feed rate and depth of cut, materials and coolant.*

**Keywords:** Cylindrical Grinding, Grinding wheel Speed, Feed Rate, Work piece speed, Depth of Cut, MRR, Surface Roughness, Taguchi method.

## I. Introduction

Globalization is posing several challenges to the manufacturing sector. Design and operation of manufacturing systems are of great economic importance. In any manufacturing sector, machining process plays a major role especially in obtaining desired shape, size and accuracy. Machining process involves the usage of single or multiple point cutting tools to remove the unwanted materials from the stock in the form of chips. Among the various metal cutting process available, grinding is one of the important metal cutting processes used extensively in the finishing operation of discrete components [1],[5].

Cylindrical grinding is an essential process for final machining of components requiring smooth surfaces and precise tolerances. As compared with other machining processes, grinding is costly operation that should be utilized under optimal conditions. Although widely used in industry, grinding remains perhaps the least understood of all machining processes [9].

## II. Literature Review

In the past recent years many researchers have suggested various methods to explain effect of cylindrical grinding process parameters on MRR and surface roughness. From this methodologies Taguchi method is the most popular one [4]. The Taguchi Technique for quality engineering is intended as a guide and reference source for Industrial practitioners (managers, engineers, and Scientists) involved in product or process experimentation and development [6]. To optimize our process or operation first we need to have the basic concepts of the following:

## III. Experimental Design Methodology

There are various methodologies which used the given process can be optimized. This methodologies are used to improve the quality of product and process. Some of widely used approaches in product/process development are [18].

- 1) Build-Test-Fix
- 2) One factor at a time

## 3) Design of experiment (DOE)

**Build test fix:** The “Build test fix” is the most primitive approach which is rather inaccurate as the process is carried out according to the resources available, instead of trying to optimize it. In this method the process/product is tested and reworked each time the result are acceptable.

**One factor at a time:** The “one factor at a time” approach is aimed at optimizing the process by running an experiment at one particular condition and repeating the experiment by changing any other one factor till the effect of all factors are recorded and analyzed. Evidently, it is a very time consuming and expensive approach. In this process, interactions between factors are not taken in to account.

**Design of experiment:** The design of experiment is considered as one of the most comprehensive approach in product/process developments. It is a statistical approach that attempts to provide a predictive knowledge of a complex, multi-variable process with few trials. The following are major approaches in DOE:[18],[19]

## - Full factorial design

A full factorial experiment is an experiment whose design consists of two or more factors, each with a discrete possible level and whose experimental units take all possible combinations of all those levels across all factors. Such an experimental allows studying the effect of each factor on the response variable, as well as on the effects of interactions between factors on the response variable.

## IV. Taguchi Method

Taguchi method is a multi-stage process, namely, 1) System/concept design, 2) Parameter design, and 3) Tolerance design. The following sections delineate the three-stage process suggested by Dr. Taguchi to achieve desirable product quality [6][16].

**System design:** is a scientific and engineering principles and experience are used to create a prototype of the product that will meet the functional requirements and also to create the process

that will build it.

**Parameter design:** involves finding the optimal settings of the product and process parameters in order to minimize performance variability. Taguchi defines a performance measures known as signal-to-noise(S/N) ratio and tries to select the parameter levels that maximizes this ratio. The term signal represents the square of the mean value of the quality characteristic, whereas noise is a measure of the variability (as measured by the variance) of the characteristic.

**Tolerance design:** in this step we set tolerances (i.e. a range of admissible values) around the target values of the control parameters identified in the parameter design phase. We do this only if the performance variation achieved by the settings identified in the parameter design stage is not acceptable.

**V. Loss function**

According to Taguchi Quality is the loss imparted to society from a time a product is shipped. The concept of loss include the expense, waste and lost opportunity that result when a product fails to meet the target value exactly. During production, costs such as inspection, scrap, and rework contributed to loss. He proposed a mathematical formula called the loss function for estimating the monetary loss caused by lack of quality. The loss function estimates loss even if parts are made within specification limits. This is necessary to allow for the fact that a company makes all parts within specification limits still has warranty and customer complaints. That is some loss associated with a population of parts no matter how well they are produced. As long as any parts differ from the target specification, there will be some loss. This loss function value is further converted into a signal-to-noise ratio(S/N). Basically, the performance characteristics have the following three categories of the S/N ratio.[18]

Target is best

Smaller is better

Larger is better

**VI. Signal-to-noise Ratio and Performance Measures**

To determine the effectiveness of a design, we must develop a measure that can evaluate the impact of the design parameters on the output quality characteristic. As note the term signal, or average value of characteristic, represents the desirable component, which will preferably be close to a specified target value. The term noise represents the undesirable component and is a measure of the variability of the output characteristic. Taguchi has combined these two components into one measure known as the signal-to-noise (S/N) ratio. Mathematical expiration for the S/N ratio are dependent on the three situations such as target is best, smaller is better and larger is better

**Target is best**

This case arises when a specified value is most desired, meaning that neither a smaller nor a larger value is desirable. The general formula for calculating the target is best S/N ratio is as follows

$$S/N \text{ ratio} = -10 \log_{10} [\text{Square of mean}/\text{Variance}]$$

The S/N ratio for each level of process or product parameters are calculated depending upon the S/N analysis results. Not taking the account of the class of quality characteristic of interest, a larger S/N ratio of the parameters is selected for better quality characteristic of interest. Therefore, the best level of the product or process factors is the level which has the highest S/N ratio.

**Smaller is better**

For ideal case desired value of S/N ratio is zero. The general formula for calculating the S/N ratio of smaller is better is

$$S/N \text{ ratio} = -10 \log_{10} [\text{mean of square of measured data}]$$

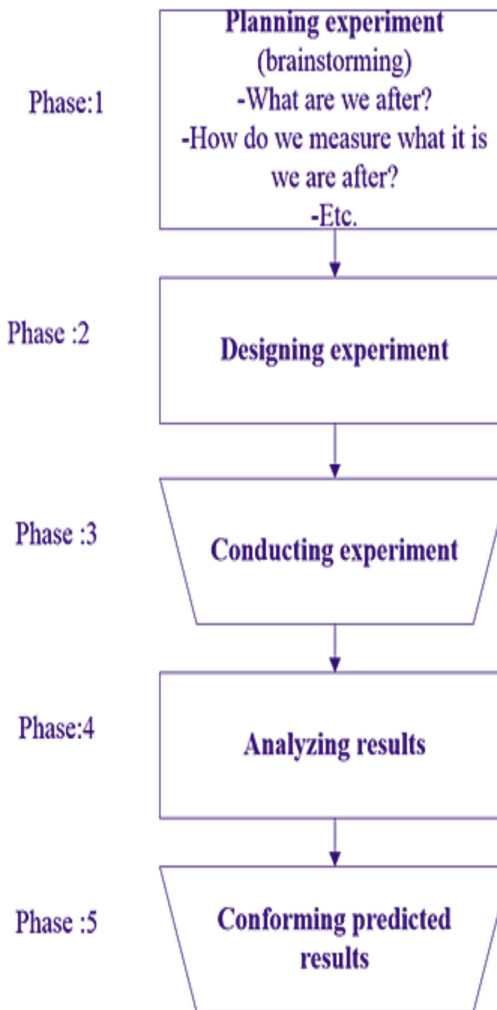
**Larger is better**

This case is opposite to smaller is the best case and it is obtained by taking the reciprocals of measured data. The general formula for calculating the larger the S/N ratio is as follows;

$$S/N \text{ ratio} = -10 \log_{10} [\text{mean of square of measured data}]$$

**VII. Steps involved in Taguchi Method**

Taguchi's parameter design involved the following steps [17]



DOE application phases: the new discipline(parallel process)

Fig. 1 Design of Experiment application phases

**Planning phase:** Formally, this is the experiment planning session, preferably facilitated by a person who is not involved in the project. All decisions about the project such as the objectives, their measurement method, and the factors that may influence the results, are made by the participating members in a democratic process in which each person has one vote.

**Designing:** the planning sessions conclude with all necessary information in place regarding the experimental strategy. Based on the factors and levels identified, an experiment is designed that readily specifies the number of experiments and the manner in which each experiment will be carried out.

**Conducting:** once the experiment are designed, they are conducted following the exact design combination recipe prescribed and in the order required by the layout for statistical validity.

**Analyzing:** in this stage the result collected from the experiment are analyzed. Analysis are standardized to determine information about the project under study. Depending on the number of samples tested in each experimental condition, different analysis technique are suggested. The primary goal of analysis is to obtain information about the new design condition and an estimate of the improvement expected.

**Confirming:** generally, the best design condition predicted by the analysis is not one that currently exists or one that has been tested. Therefore, to verify if improvement is really achievable

or to determine how close the estimate matches actual performance, a number of samples made to the new design specifications are tested[17],[18]

**VIII. Selection of Orthogonal Array (OA)**

In selecting an appropriate OA based on

- Selection of process parameters and interaction to be evaluated
- Selection of number of levels for the selected parameters
- Cost consideration

Several methods are suggested by Taguchi for determining which parameters to include in an experiment. These are

- a) Brainstorming
- b) Flow charting
- c) Cause-Effect diagram

The total degree of freedom (DOF) of an experiment is a direct function of a total number of trails. If the number of levels of a parameter increases, the DOF of the parameter also increases because the DOF of a parameter is the number of levels minus one. Thus, increasing the number of levels of a parameter increases the total degree of freedom in the experiment which in turn increases the total number of trials. [17],[18] Orthogonal arrays most commonly used for experiment design shown below the table1.[18]

Table 1 Most commonly used OA and its levels

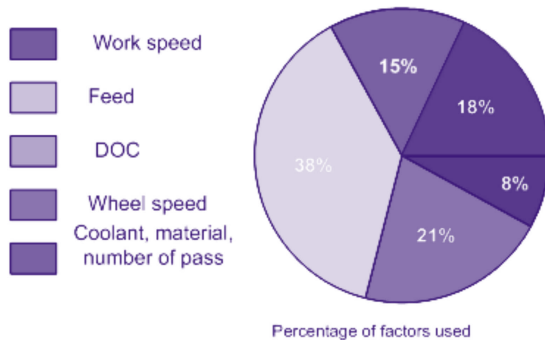
Array	Intended use (experiments with)	
L-4 (2 <sup>3</sup> ) L-8 (2 <sup>7</sup> ) L-12(2 <sup>11</sup> ) L-16(2 <sup>15</sup> ) L-32(2 <sup>31</sup> )	3 two- level factors 7 two- level factors 11 two- level factors 15 two- level factors 31 two- level factors	Two- level arrays
L-9(3 <sup>4</sup> ) L-18(2 <sup>1</sup> , 3 <sup>7</sup> ) L-27(3 <sup>13</sup> )	4 three- level factors 1 two-level and 7 three-level factors 13 three-level factors	Three-level factors
L-16(4 <sup>5</sup> ) L-32(2 <sup>1</sup> , 4 <sup>9</sup> )	5 four level factors 1 two level and 9 four-level factors	Four- level factors

Table 2: Summary of literatures which done the past recent years

Year	Author's Name	Material	Tool	Parameters	Quality parameter	Most significant
2010	KomsonJirapatarasilp, SittichaiKaewkuekoolPeeranutKlahan	AISI 4140 Hardened 5 $\pm$ 3 HR	38A-60K V35	work speed feed rate depth of cut	Surface- roughness Roundness	depth of cut
2011	Kirankumar R.Jagtap, S.B.Ubale , Dr.M.S.Kadam	Hardened AISI 1040	Al2O3	depth of cut Work Speed Number of Passes Wheel Speed	surface roughness MMR	work speed Number of passes
2011	Kirankumar R.Jagtap, S.B.Ubale, Dr.M.S.Kadam	Hardened AISI 5120 58HR	Al2O3	depth of cut Work Speed Number of Passes Wheel Speed	surface roughness MMR	work speed Number of passes
2012	Kundan Kumar, S.Chattopadhyaya Hari Singh	mild steel		depth of cut cutting speed	MMR	Cutting speed
2013	Lijohn P George, K Varughese Job I M Chandran	EN 24, EN31 EN 353	AA46K5V40	depth of cut material hardness work speed	surface roughness	hardness
2013	Pawan Kumar Anish Kumar Balinder Singh	EN24	Al2O3	Wheel speed Table Speed Depth of cut	surface roughness MMR	
2014	M.Melwin Sridhar M.Manickam, V.Kalaiyaran M.Abdul Ghani Khan Ttm.Kannan	AISI 0-1		work speed depth of cut number of passes	MMR	Number of pass
2014	K Mekala, J Chandradas, K Chandrasekaran, T T M Kannan, E Ramesh R NarasingBabu	AISI 316 Hardened 55 HRC		cutting speed, feed rate Depth of cut	MMR	Depth of cut
2014	Suresh P. Thakor	EN8		work speed cutting fluids depth of cut	surface roughness MMR	
2014	M. Ganesan, S. Karthikeyan N. Karthikeyan	304 stainless steel		Cutting speed Feed rate Depth of cut	surface roughness	Cutting speed
2015	Sandeep Kumar Onkar Singh Bhatia	EN15AM (0.3 to 0.4)		wheel speed work speed feed depth of cut cutting fluid	MMR	Work piece speed
2015	S. M. Deshmukh, R. D. Shelke C. V. Bhusare	OHNS (Hardened)	Al2O3	Spindle Speed Feed Depth of cut	surface roughness MMR	Feed rate Depth of cut
2015	Naresh Kumar HimanshuTripathi SandeepGandotra	C40E steel 0.4-0.45		speed feed depth of cut	surface roughness	feed
2016	Prashant J. Patil C.R. Patil	EN8		depth of cut type of lubricant wheel speed coolant flow rate nanoparticle size	G ratio surface finish	coolant
2016	Cetin Ozay HasanBallikaya VedatSavas	AISI D3 tool steel		Depth of cut Wheel speed Workpiece speed	surface roughness	All

## IX. Conclusion

From the above literature review we found that most of the researchers have taken input parameters (controllable factors): work speed (7 research papers out of 15 mentioned above), feed 6/15 and depth of cut 15/15, wheel speed 8/15, coolant 1/15, material 1/15, number of pass 1/15 and, output parameters: surface roughness for grinding 6/15, material removal rate (MRR) for grinding 4/24 else use both as a response parameters.



**Fig. 2** The pie chart indicates the frequency percentage of process parameters used

## X. Identification of the gaps in literature review

After a detailed study of existing literature the following gaps have been observed in cylindrical grinding process

- 1) Most of the researchers have investigated the influence of a limited number of process parameters on cylindrical grinding process which leads to incorrect conclusion
- 2) Only a few researchertaken coolant asinput parameter which indicated in the table it will be most significant factor when we use it.
- 3) No researchers worked so far on EN 45, which have so many applications like spring, airplanes, military, weaponry, rail transportation, bridges, machine tools and knives and swords.

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## AUTHOR

**Nesredin Chekole**, M.E. (Industrial Engg.) 4th Semester Student, G H Patel Collage of Engineering & Technology, Vallabh Vidhyanagar, Gujarat, India  
Email : nesru78chekole@gmail.com

**Dr. Vivek Deshpande**, Assistant Professor, Dept. of Mechanical Engineering, G H Patel Collage of Engineering & Technology, Vallabh Vidhyanagar, Gujarat, India  
Email : vivek\_deshpande@yahoo.com