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Analysis of Surface Grinding Response Parameter for EN31 Alloy Steel using Taguchi Methodology & Artificial Neural Network and Compression with Cylindrical Grinding Performance Parameter

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Abstract*: Surface finish is extremely important in the manufacturing industry, because getting the correct surface quality is critical. Industries use grinding operations to achieve the desired surface polish on products. Grinding techniques include surface grinding, cylindrical grinding, centerless grinding, and creep-feed grinding. Cylindrical grinding is a machining technique used to refine the external surface of a workpiece. This process involves rotating the workpiece on its axis as a grinding wheel meticulously eliminates material, resulting in the ideal form, size, and surface texture. The work material used in these trials is EN31 steel, which is frequently used in the automobile industry to produce shear blades, molding dies, bolts, and cutting tools. Performance metrics including surface roughness and metal removal rate are assessed using three input parameters: wheel speed (V), depth of cut (D), and number of passes (N) throughout different ranges. Artificial Neural Network (ANN) study carried out in MATLAB software and Taguchi Design utilizing MINITAB are used to discover optimal performance parameters. The ANN receives its input data from the Taguchi method. The lowest surface roughness (Ra) of 0.12000 µm and the highest metal removal rate of 0.83406 grm/sec are shown by the results. Notably, the two most important variables in the surface grinding process are wheel speed and number of passes*

Keywords: Surface Grinding Machine, surface roughness, MRR, Taguchi Method, Wheel speed, cutting depth, and number of passes

I. INTRODUCTION

Surface Grinding is a metal removal process to obtain fine finishing on hardened material, with a high grade of surface finish in close geometric tolerances and high dimensional accuracy. In order to control the metal removal rate and achieve the better finish on the object the multi cutting edge grindingtool is used. In grinding process power is supply to the grinding wheel that causes friction between the tool and workpiece, due to this friction the metal is remove by the surface of the object in the form of fine particle. Grinding is fine machining process which provides good surface finish on an object by the removal of small amount of material in the form of small tiny microscopic particles from the surface of an object.

To combine low surface roughness and high metal removal rates, EN31 steel is used in this experimental study. The superior quality and high carbon content of EN31 alloy result in remarkable hardness, compressive strength, and abrasion resistance. EN31 alloy steel is frequently used in the automobile industry for the production of a wide range of components, including as punches, shafts, studs, bolts, heavy-duty gears, pinions, camshafts, and gudgeons. Dr.

Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a very fine method based on 'Orthogonal Array' which provides much variance for experiments with optimum settings of control parameters. The special set of Arrays called Orthogonal Arrays are used in this method.

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MNITAB is software which use for statistical Analysis. For learning about statics as well as numerical exploration, this software is very helpful to fulfil these requirements. This software is used in quality control of chemical inspection.

1.1 Grinding process

In earlier stage chisel was used as the most suitable tool for removing metal. Chisel has a one cutting edge for remove the metal and more metal can be removed by it with very poor finish. To obtain the good finish on the surface of the object multi cutting edge tool file was used. Material removal rate is very less, but the better finish can be obtained. Similarly, in order to control metal removal and obtain the good surface finish by the use of multicutting edge tool. The grinding process improves the geometric accuracy of the object (± 0.02mm) and improves surface finish upto 0.1µm [1].

Grind means 'to abrade', to wear away by the friction' or 'to sharpen'.Material is removed from the surface of the object by the means of rotating abrasive wheel. The grinding process is sometimes used for the machining of hard object which cannot be machined by the other high speed tools or carbides tools. The grinding wheel is made up of abrasive particles that provide large number of cutting edge on outer layer of grinding wheel.

Abrasive particles that are used in grinding process have high hardness. Abrasive particles less sensitive to heat compared to other materials and can sustain higher temperature. From the above quality of abrasive particles the grinding wheel can worked at high cutting speeds. A very little pressure required in the grinding process to remove the metal from the surface of the object, that characteristic permits the use of magnetic chuck for holding the work piece on work table in grinding operations [1].

Grinding wheel consist of an abrasive particles, bonding materials and voids. Each abrasive particle on grinding wheel act like a sharp tip of cutting tool, this sharp tip of cutting tool remove the metal from the object. As cutting action proceeds, the cutting edge of an abrasive particles become dull, the grinding wheel cracked along the fracture planes due to interference by the workpiece material, which conflict the cutting action. Thus new cutting edge is required for improve the cutting action of grinding wheel, for obtain the new cutting points on the external layer of the grinding wheel, Dressing and Turing two process are required [1].

1.2 Objective of work

The objective of this research work is as follows:

- Selection of appropriate input parameters for machining of EN31 material in surface grinding process.
- To achieve good surface quality, dimensional accuracy, maximum material removal rate and minimum surface roughness.
- To optimize surface roughness and metal removal rate.
- Optimization of taguchi method and compare the result with cylindrical grinding process prametrers.

II. LITERATURE REVIEW

A. Saravanakumar et. al [20]analyzed the surface grinding performance factors such as grinding wheel speed, table speed, and depth of cut in terms of high surface finish and MRR during the machining of carbon steel (AISI1042) material with EKR46K grinding wheel. They conclude the result on different machining conditions to obtain the optimum value of parameters by using DOE. Initially they selected wheel speed (1850 rpm), feed rate of (3 m/min), and the depth of cut of (0.04 mm) and analyzed that depth of cut is the major control parameter among the three controllable parameters on surface roughnessand wheel speed and table speed have minor effect on (Ra). The above parameters of surface grinding are than optimized by the using of Taguchi Method L18 OA of design experiments.

Zhao Tao et. al [21] performed experiment on titanium alloy at five axis CNC grinding machine with the surface grinding input parameters such as cutting velocity, feed rate, grinding depth, abrasive size in terms of MRR and surface integrity. They conclude that the surface parameters are affected by the grinding parameters. Each grinding parameter has different level of influence on surface parameters; the residual stress is the most susceptive to the change of feed rate, hardness is significantly affected by grinding depth, and MRR is vastly impressed by the abrasive size.

Wei Liu et. al [22] have discussed the L16 orthogonal experiments on Silicon Nitride Ceramic (Si3N4) with the diamond grinding wheel and includes such input parameters as the grain size, wheel speed, and grinding depth, and

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explore their influence on grinding force, , surface roughness.. They stated that grinding force is less than 14N/mm, and the grinding force ratio between 6 and 14 for Si3N4. They also determine that the tangential force increases, with the increases of grain size, which is supportive for material removal rate, and increasing grain size and wheel speed, but surface roughness and surface damage depth decreases and with the increasing workpiece speed and grain depth, and (Ra) and surface damage depth increases.

Amandeep Singh Padda et. al [23] stated that in surface grinding, process parameters has a very important role in hindering the performance of the apparatus and machine tool.. The tangential force increases with the increasing wheel speed thus permit the more material removal rate and less cultivation and damage of grains, but increases stress on wheel due to rigidity and durability of the stainless steel, thus increase the high grain apparel and unusual fracture. They stated that Al2O3 grain size wheels not able to produce superior finish at high wheel speed, thus it is not use for grinding stainless steel..

B. Dasthagiri et. al [24] performed an testing on EN8 steel using CNC grinding machine contain such input parameters as wheel speed, table speed, depth of cut. For this experimental work they mainly focus on developed the empirical model using RSM, to find optimum machining parameters such as minimizes (Ra) and maximum MRR, ANOVA used for sufficiency of the model based on output response and metal removal rate by considering the input parameters. They analyzed that the output parameters influenced by the input parameters and the (Ra) or MRR much be subject to the object material.

T.V. Mahajan et. al [25] presented to find the optimum process parameters in surface grinding process by the experiment on AISI D2 steel using special purpose grinding machine. In this experimental work the input parameters are deliberated as wheel grain size, wheel speed, table speed, and depth of cut. Optimum output parameters are maximum MRR and minimum (Ra) obtained by using Taguchi L9 OA method and ampleness of the processed model examine with (ANOVA). They determine that the surface roughness majorly effected by the table speed, and MRR has affected by the depth of cut.

Pawan Kumar et. al [26] performed an experimentation on EN24 steel at CNC grinding machine with the surface grinding process parameters such as grinding wheel speed, table speed, and depth of cut in terms of surface superiority and metal removal rate. The methodology adopted in this study (RSM) was employed to define the finest machining parameters trends to minimum (Ra) and maximum MRR in grinding process. They accomplish that experimental data match the predicted data and the error between performed values and predicted data lie within 4.96% and 4.30% at the optimal sets of parameters for MRR and Ra respectively.

III. MATERIAL & METHODOLOGY

In this experimental workthe material EN31 steel is used to obtain low surface roughness and high metal removal rate. Rectangular block of 100 mm × 20 mm× 16 mm thickness prepared of EN31 tool steel is used and machining accomplish on the surface grinding machine. High carbon alloy steel with high degree of hardness, compressive strength, and abrasion strength are the properties of EN31 tool steel, which is pick out for obtaining the optimum parameters.

3.1 Design of experiments

DOE is a process in which control factor levels are arranged according to a methodology and on the basis of this arrangement experiments are performed. The aim of design of experiment is to find the influence of control factors on response factors by reducing the influence of noise factors and to increasing the quality of the product and process by reducing manufacturing losses, wastage of material and risk of failure.

TABLE 3.1: CONTROL FACTOR LEVELS

Control factor	**Units**	**Levels**			
		(i)	**(ii)**	**(iii)**	**(iv)**
No. of Passes	Nil	1	2	3	4
Wheel speed	rpm	375	750	1125	1500
Depth of Cut	mm	0.02	0.04	0.06	0.08

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3.2 Taguchi approach

Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a very fine method created on 'Orthogonal Array' experiments which provides much variance for experiments with optimum settings of control parameters. To get better the quality of manufacturing components and elevate the process parameters, the arithmetical approach Taguchi method is used. The application of Taguchi Method was expanded to getting better quality of manufacturing goods and other fields such as biotechnology. Desired result is successfully found by this method for the collection of input parameters and brief them into control factors. For obtaining the optimum result of the process, the proper control of factors involved by the Taguchi Method.

This method has the frequent application in manufacturing area mainly in automotive industries and plastic industries, and metal fabrication.

Taguchi method was used to determine optimized parameters combinations, with the minimized number of experiments. For process optimization the Taguchi method is used. For reduce the cost and enhance the quality of work, this technique is used

3.3 Artificial neural network

The structure of ANN is made by artificial that are interconnected with each other called Artificial Neural Network. To create the simulated brain the neural network theory revolves, in the order of that definite input property of biological neurons can be extracted and applied to simulations. The human brain processes information, as like human brain, the neural networks are capable to process the facts in indistinguishable way.

Artificial Neural Networks are comparatively basic electronic models based on the neural structure of the brain. From the no of attempts brain learn a new thing in each attempt and each attempt brain got the experience to solve the problem and attempt the problem in different way, as the same the artificial neural network work at same approach.The ANN is new approach to computing the problem and also provides the better results during system overload.

3.4 Working of artificial neural network

A neuron is important processing part of a neural network. A biological neuron receives inputs from other sources, combines in some way, perform a nonlinear operation on result, and the output is final result. The neural network has four basic components and these components are known as biological names dendrites, soma, axon, and synapses. The hair likes structure known as dendrites its extension of soma which acts like input channels and through the synapses the input channels receive their input channels, and then soma processes the input signal and turns the input value into output value which is sent to other neurons through the axon and the synapses.

The three-dimensional world from infinitesimal components neural networks is constructed and these neurons look like proficient of nearly unrestricted interconnections, this is not true for any proposed, or existing, manmade network. In the current time combined technology, have two dimensional devices with a limited number of layers for interconnections. This substantial certainty controls the types, and scope, of artificial neural networks that can be implemented in silicon.

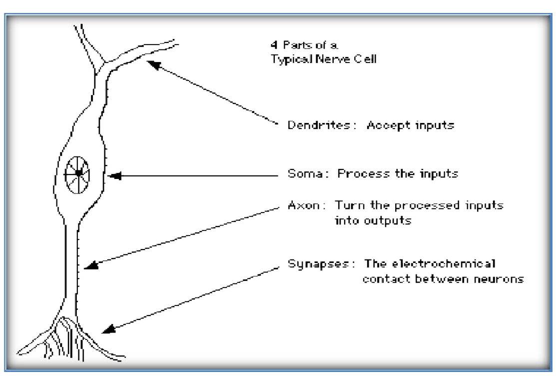

Fig. 3.1 A simple neuron

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IV. EXPERIMENTAL OBSERVATIONS

4.1 Planning of workpieces

For the experimental observation EN31steel is used as stated before. Total 16 rectangular bars of EN31 steel is selected as workpiece. Initially bars have a thickness of 15 mm to 20 mmlength 100 mm to 110 mm and width 20 mm to 25 mm as shown in fig. 4.1.

Fig. 4.1 Specimen at initial condition

TABLE 4.1: SPECIFICATION OF SURFACEGRINDING MACHINE

Machine Model	E_6030_NC
Automation Grade	Automatic
Brand	COSMOS IMPEX
Machine Type	Numeric Control Surface grinding
Max Allowable Length of Workpiece	250 × 500 mm
Controlled Axis	X, Y, Z
Longitudinal Travel	650 mm
Cross Travel	320 mm
Maximum Distance Center of Spindle to Table	400 mm
Vertical Down Feed on Hand Wheel	0.001 mm
Grinding Wheel Dimensions (OD × W × ID)	203 × 20 × 50.8 mm
Grinding area	650 × 500 mm
Spindle Motor	2.2KW

4.2 Process parameters

For surface grinding process two types of parameters are selected. Efficiency of machining process is measured with response parameters are called as first parameters. On the basis of necessities such as quality and quantity these parameters are selected. In this research work we use EN31 steel as work-piece and response parameters for this experimental work are shown as follow:

- Surface roughness (Ra)
- Material removal rate (MRR)

Machining parameters depends on control parameters are called as second parameter. On the basis of some investigation paper we accomplish that some control parameter produce most vital effect on surface roughness and material removal rate, these parameters are:

- No of passes (N)
- Wheel Speed (V)
- Depth of cut (D)

The range of control factors for the selected machine is shown in table 4.2.

TABLE 4.2: RANGE OFINPUT PARAMETERS

S. No.	Parameters	Units	Range
1	No of Passes (N)	Nil	- 4
2	Wheel Speed (V)	rpm	375-1500
3	Depth of cut (D)	mm	0.01mm -1mm

4.3 Experimental results

As per Taguchi design of experiments all the experiments are performed successfullyon surface grinding machine. The best process quality and optimum condition has been considered in this experimental work. Surface roughness and Metal Removal Rate readings for all 16 objects are measured and response tables for them are given in table 4.3.

TABLE 4.3: EXPERIMENT RESULTS

No. of Exp.	No of Passes (N)	Depth of Cut (D) mm	Wheel Speed (V) rpm	Material Removal Rate (grm/sec)	Surface Roughness (μm)
1.	1	0.02	375	0.42477	0.21668
2.	1	0.04	750	0.82967	0.20001
3.	1	0.06	1125	0.44669	0.14335
4.	1	0.08	1500	0.83406	0.23667
5.	2	0.02	750	0.11276	0.21668
6.	2	0.04	375	0.10599	0.17659
7.	2	0.06	1500	0.22950	0.13668
8.	2	0.08	1125	0.33789	0.15669
9.	3	0.02	1125	0.08000	0.20000
10.	3	0.04	1500	0.10987	0.12000
11.	3	0.06	375	0.20685	0.18669
12.	3	0.08	750	0.10669	0.22670
13.	4	0.02	1500	0.27586	0.15685
14.	4	0.04	1125	0.08295	0.24690
15.	4	0.06	750	0.07705	0.33346
16.	4	0.08	375	0.08323	0.23001

The above experimental data shows that maximum MRR is 0.83406 grm/sec obtained at experiment no 4 which has one number of pass, 0.08 mm of depth of cut and wheel speed of 1500 rpm and minimum Ra 0.12000 (μm) is obtained at experiment no 10which has three number of pass, 0.04 mm depth of cut and wheel speed of 1500 rpm.

The main effects plots of MRR v/s control parameters and Ra v/s control parameters are shown in fig. 4.9 and fig. 4.10. Main effect plot shows that for MRR and Ra, the Wheel speed and no. of passes are the most effective parameters.

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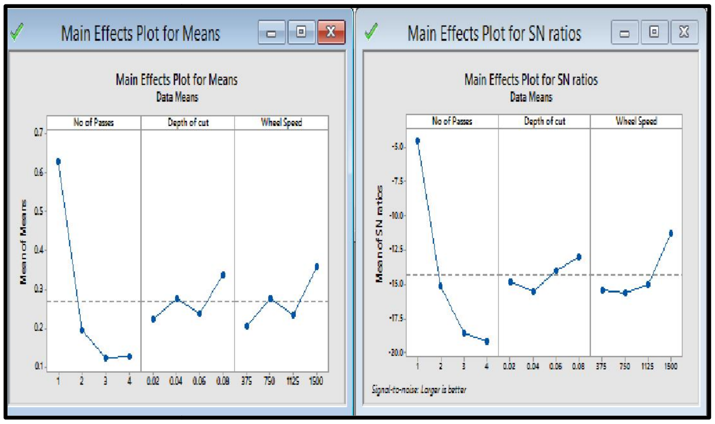

Fig. shows that when the no. of passes increases metal removal rate decreases and MRR increases when we increase in depth of cut and wheel speed.

S/N data analysis has been performed in this experimental work. From the analysis of S/N ratio it is found that for MRR, no of passes is highly effective parameter (with maximum delta of 14.785) and wheel speed (with delta of 4.365) produces moderate effect and depth of cut (with lowest delta of 2.499) produces least effect. According to the effect of control parameter on MRR we mark first rank to no of passes, second rank to wheel speed and third rank to depth of cut.

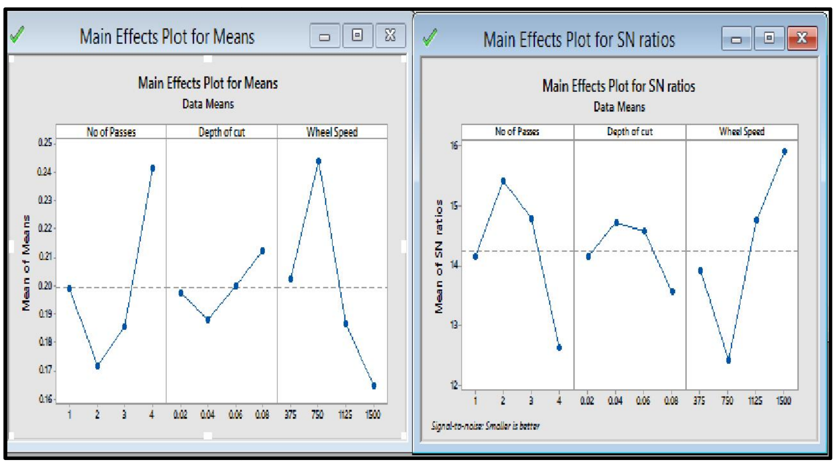

Fig. 4.9 Ra v/s Control parameters

V. RESULTS OF RA AND MRR

The experiments are conducting on EN31 alloy steel in surface grinding process it is found that:

- EN31 steel alloy is capable of producing desired surface quality at various experimental conditions.
- The optimal data for surface roughness (Ra) is 0.12000(µm) obtained.
- The optimal data for material removal rate (MRR) is 0.83406 (grm/sec) obtained.
- Cylindrical grinding machine is capable to produce minimum surface roughness and maximum MRR with EN31 alloy steel in following condition:
- The combination of process parameters for optimized multi-response parameters are workpiece speed of 112 rpm, table feed rate of 66.4 mm/sec and depth of cut of 0.08 mm.
- The optimal value for surface roughness (Ra) is 0.80667µm obtained in cylindrical grinding process.
- The optimal value for material removal rate (MRR) is 1.25628 gram/secobtained in cylindrical grinding process.

VI. CONCLUSION

In this experimental research work developed model of ANN is used to measure the surface roughness and material removal rate of EN31 alloy steel in surface grinding process. The following conclusions are made from the analysis:

- Computer based software's as Taguchi design of experiments in MINITAB and ANN in MATLAB are successfully applied for the prediction of Ra and MRR.
- Wheel speed and no. of passes are the most dominating input parameters for both surface roughness and material removal rate anddepth of cut is least effective parameter.
- For EN31 steel following results are optimized as follows:
- Minimum surface roughness is found at experiment no 10, no of passes 3, depth of cut 0.04 mm, and wheel speed 1500 rpm.
- Maximum material removal rate is found at experiment no 4, no of passes 1, depth of cut 0.08 mm and wheel speed 1500 rpm.

VII. FUTURE SCOPE OF WORK

After completion of experimental work, analysis of process parameters, study of surface grinding process, important concepts of artificial neural network and practical work opportunities of future work are as follows:

- Artificial neural network technique is not only for surface grinding process it can be used for cylindrical grinding and other process.
- Surface grinding process can be extended further, by selecting other materials or steel alloys.
- After implementing the artificial Neural Network we can further analysis this data as input in GRA for improving the efficiency of the experimental research work.

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