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Optimizing Cylindrical Grinding Proficiency and Surface Finish for EN24 Steel Alloy with the Use of Taguchi Analysis and Artificial Neural Network

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Abstract: *Grinding is a material removal procedure used at the end of manufacturing to obtain high dimensional precision and a desirable surface polish. External cylindrical grinding is a type of grinding procedure that used to grind cylindrical things such as engine shafts, connecting rods, spindles, and axles. This study examines how control settings affect response parameters using EN24 alloy steel on a cylindrical grinding machine. Response parameters are material removal rate (MRR) and surface roughness (Ra), whereas control parameters are workpiece speed (v), feed rate (f), and depth of cut (d). Taguchi DOE is employed with L16 orthogonal array to optimize control parameter levels, followed by cylindrical grinding tests.An artificial neural network (ANN) model was created to validate and predict cylindrical grinding reaction parameters. To train the network, experimental data was used, and ANN predictions were compared to real data. Data collection has also completed.In the purposed work minimum Ra is 0.52 µm and maximum MRR is 0.6588 g/sec found and results indicate that feed rate and workpiece speed are the most dominating parameters of cylindrical grinding. The experimental results can be employed by various manufacturing and industrial firms and they can select suitable combinations of input parameters for desired Ra and MRR.*

Keywords: Cylindrical grinding, Surface roughness, Material removal rate, Taguchi method, artificial neural network

I. INTRODUCTION

1.1 Introduction

Manufacturing industries aim to meet key objectives such as high quality, dimensional accuracy, productivity with minimal cost, and reduced material wastage. To achieve these goals, they employ various machining methods and techniques. Grinding, in particular, is an effective material removal process for hard materials, providing the necessary surface finish and tight tolerances.

EN24 alloy steel is increasingly being used in different industrial applications such as high strength shafts, punches, dies, bolts, studs, screws, rollers, and in the automotive industry for gears, heavy duty axles, connecting rods, and so on. It is a high-strength alloy steel that has high tensile strength while remaining ductile and wear resistant. So, EN24 was chosen as the workpiece material and processed using an external cylindrical grinding machine.

The current work demonstrates the estimate of response parameters for a cylindrical grinding operation. Taguchi design of experiments and L16 orthogonal array were used to determine the best combination of control parameters workpiece speed (v), feed rate (f), and depth of cut (d) at various levels. According to the design of the experiment, sixteen specimens were machined using external cylindrical grinding, and the effects of control parameters on response parameters material removal rate (MRR) and surface roughness (Ra) were investigated.

An artificial neural network (ANN) model has been developed for estimating cylindrical grinding reaction parameters. The network was trained using experimental data. The trained ANN model can predict response parameters. Following the development of an ANN model, gray relational analysis (GRA) is used to optimize multi-response variables.

1.2 Surface finishing process

Various machining processes are conducted on the workpiece material to achieve the appropriate product shape and size with a high surface finish and close tolerance by removing surplus material in the form of chips. When a workpiece is subjected to various manufacturing techniques, strong mechanical forces and localized heating are involved, resulting in machining markings on the workpiece surface. Together with the machine, the work piece, and the tool on which they are placed, they form a vibratory system that causes random, forced, or induced vibrations. Vibrations cause damage to machined component surfaces in terms of surface polish and integrity. The degree of surface finish defines the geometry and microstructural quality.

II. LITERATURE SURVEY

2.1 Literature review

The literature survey includes research papers related to cylindrical grinding process which was used for machining of different materials like EN15AM Steel, C40E Steel, 304 Stainless Steel, EN 19, EN 31,Alloy steels on different machining conditions. These papers also define the current research trends in cylindrical grinding process. The following papers highlight the use of different input process parameters and use of different methodologies like ANN, ANOVA, Taguchi, GRA, RSM, etc.

From the study of papers observed that for machining processes, use of ANN is less so in this research work ANN methodology selected for estimation of cylindrical grinding response parameters. Looking at increasing use of EN24for different purpose, it has been machined on cylindrical grinding machine and response parameters are analyzed. On the basis of papers control parameters for cylindrical grinding are workpiece speed (v), feed rate (f), depth of cut (d) and response parameters are material removal rate (MRR) surface roughness (Ra) selected.N. Sudheer Kumar Vermaet. alThe influence of workpiece speed, depth of cut, and feed rate on the material removal rate and surface roughness of Inconel 800 alloy in a cylindrical process was investigated. A total of 27 experimental data are collected using a full factorial design, with three levels for each parameter during the machining process. The results of the studies are utilized to train regression models, neural networks, and the adaptive-neuro fuzzy interface system (AFNIS). Ra was shown to decrease with increased workpiece speed and depth of cut, but increase with increased feed rate. Similarly, when workpiece speed increases, MRR drops but increases with depth of cut and feed rate. For Ra, the optimal machining parameters were 400 rpm of workpiece speed, 400 microns. M. Ganesan et. al selected cutting speed, feed rate and depth of cut as input parameters and find out the effect of these parameters on Ra of 304 stainless steel by using 9 specimen rods of 20 mm diameter and 100 mm length each. Author selected taguchi design of experiments of L9 orthogonal array with 3 different levels and 3 different factors. In order to determine most effective input parameters for the response parameters ANOVA (Analysis of Variance) is used. The optimum values of input process parameters for minimum Ra in the cylindrical grinding of 304 stainless steel rods were 780 m/min of cutting speed, 0.093 mm of feed rate and 0.005 mm of depth of cut found. Author also concludes that increase in cutting parameters results in poor surface finish.Ravi Kumar Panthangiet. alselected three different alloys i.e. EN19, EN24, EN31 alloy steels of different hardness. The main reason of author to select three different alloys was to find out the effect of input process parameters material hardness, workpiece speed and depth of cut on surface roughness in cylindrical grinding. Experiments are performed in the order given by taguchi method as per L9 orthogonal array. The experiment results are used in MATLAB software and genetic algorithm was applied to find the optimum values. Author found that hardness has a major effect on Ra. The calculated data for minimum surface roughness is hardness of 40, workpiece speed of 214 rpm and depth of cut 1mm.SaikatChatterjeeet. alinvestigated the significance of process parameters on aluminum bronze material in cylindrical traverse cut grinding process. The Ra data is analyzed by S/N ratio and graphical presentation in Minitab. It was found that longitudinal feed is the most significant factor for Ra and workpiece speed is the least significant factor. For minimum Ra the optimal conditions are longitudinal feed of 70 mm/sec, workpiece speedof 315 rpm and infeed of 0.008 mm/cycle.Ramesh Rudrapati et. alfound the effect of infeed, longitudinal feed and workpiece speed on Ra and vibration in Cylindrical grinding of cold rolled stainless steel of SS410 grade. Author used Box-Behnken design matrix and response surface methodology to find out the relation between input and output parameters and multi-objective genetic algorithm was used for optimum result. For Ra the most significant parameters were longitudinal feed and workpiece speed. For minimum Ra of 0.62 µm, the infeed was 0.04 mm/cycle, longitudinal feed is 88 mm/s and workpiece speed is 80 rpm.

III. MATERIAL AND METHODOLOGY

3.1 Material used in research

In the present research EN24 steel alloy is used as workpiece material. The EN24 alloy steelis widely used for various industrial purposes like high strength shafts, punches, dies, bolts, studs, screws, rollers etc. and in automobile sector like gears, heavy duty axles, connecting rods etc.

EN24 steel is also specified as 817m40. In the market EN24 is generally supplied as T condition which means a tensile strength of 850-1000 N/mm^2. EN24 is renowned for its excellent machinability with wear resistance properties, high tensile strength, hardness, corrosion resistance which are the basic requirements of today's manufacturing industries. Due to its good strength and hardness it provides very good surface finish at greater tolerance.

3.2 Design of experiment (DOE)

DOE is a procedure in which control factor levels are organized using a methodology, and experiments are conducted based on this arrangement. The goal of experimental design is to determine the influence of control variables on response factors while limiting the influence of noise factors, as well as to improve product and process quality by lowering manufacturing losses, material waste, and the risk of failure.

DOE experiments are conducted with varying levels of control parameters. Following experimentation, the effect of control factors on response factors is studied to determine the optimum levels at which best performance is attained. Different DOE strategies are available for experimental design, however the decision is based on the type of problem, the number of experiments, and the parameters. In the current study, the taguchi technique is applied.

IV. EXPERIMENTAL OBSERVATION

4.1 Preparation of workpieces

As mentioned before for the experiment EN24 steel is used. Total 16 cylindrical bars of EN24 steel is selected as workpiece. Initially the bars have a diameter of 32 mm and length of 120 mm to 125 mm as shown

After it the turning operation was performed on each and every specimen with the help of lathe machine.

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Now the specimens are ready for experiments. The specimens are marked numbers from 1 to 16 so that the experiment can be conducted by L_{16} orthogonal array. The marking on specimens are shown

V. EXPERIMENTAL RESULTS

All of the experiments on the cylindrical grinding machine were completed satisfactorily in accordance with Taguchi's plan. The ideal conditions for the highest process quality have been studied. Material removal rate and surface roughness data for all 16 samples are taken, and response tables are shown in Table

TABLE: EXPERIMENT RESULTS

No. of Exp.	Work Piece Speed (v) RPM	Depth of Cut (d) mm	Feed Rate (f) mm/min	Material Removal Rate (MRR) g/sec	Surface roughness (Ra) µm
1	40	0.02	30	0.0927	0.5230
2	40	0.04	60	0.1579	0.6600
3	40	0.06	90	0.1413	0.6233
4	40	0.08	120	0.2941	1.1100
5	80	0.02	60	0.2157	0.7800
6	80	0.04	30	0.0546	0.6667
7	80	0.06	120	0.2600	1.1033
8	80	0.08	90	0.2111	0.9300
9	120	0.02	90	0.2568	1.0033
10	120	0.04	120	0.4130	1.7033
11	120	0.06	30	0.1000	1.4700

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12	120	0.08	60	0.2805	2.7233
13	160	0.02	120	0.6588	4.4467
14	160	0.04	90	0.2432	4.4067
15	160	0.06	60	0.1797	3.2400
16	160	0.08	30	0.1644	2.5800

From the above received experimental data it is clear that maximum MRR 0.6588 g/sec is obtained at 160 rpm of workpiece speed, 0.02 mm of depth of cut and 120 mm/min of feed rate. Similarly, minimum Ra 0.5230 µm is obtained at 40 rpm of workpiece speed, 0.02 mm of depth of cut and 30 mm/min of feed rate.

The main effects plot of machining parameters versus response parametersare shown in Fig. 4.10 and fig 4.11. Main effect plot shows that for MRR and Ra the workpiece speed and feed rate are the most effective parameters.

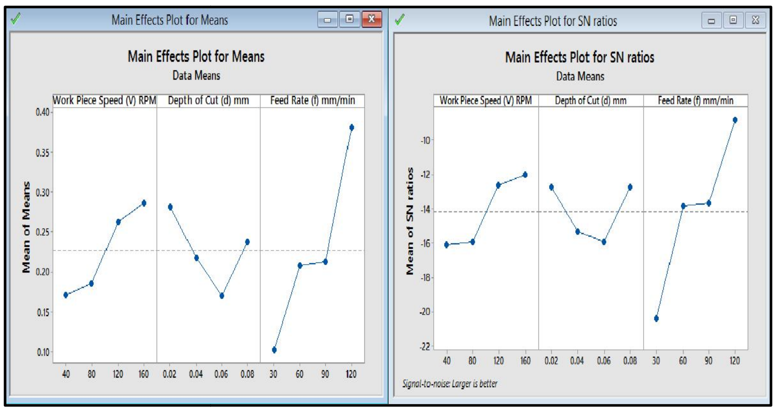

Fig. MRR vs Control parameters

Fig. 4.10 shows that increase in workpiece speed and feed rate increases MRR and increase in depth of cut decreases MRR.

In the present work, S/N data analysis has been performed. From the analysis of S/N ratio it is found that for MRRfeed rate highly affects (with highest delta of12.63) then workpiece speed (with delta of5.09) then depth of cut (with lowest delta of 2.19).

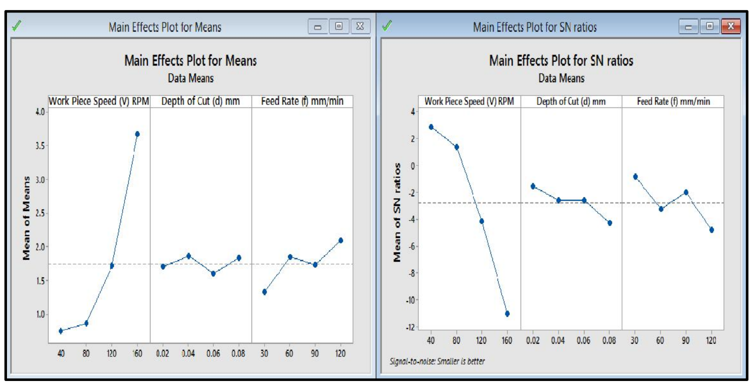

Fig. 4 Ra vs Control Parameters

Similarly, for Ra workpiece speed highly affects (with highest delta of3.92) then feed rate (with delta of0.6532) then depth of cut (with lowest delta of 0.15).

The data obtained from experimentation used for estimation of cylindrical grinding process parameters by using ANN approach. For training of ANN this data will be divided in two subsets, first is input data set and second is output data set. This trained neural network is used to get predicted values of cylindrical grinding response parameters.

VI. RESULTS FOR RA AND MRR

- After conducting the experiments on EN24 alloy steel in cylindrical grinding process it is found that

- EN24 steel alloy is capable of producing desired surface quality at various experimental conditions.
- The optimal value for surface roughness (Ra) is 0.52 µm obtained.
- The optimal value for material removal rate (MRR) is 0.6588 g/sec found.

VII. CONCLUSION

- The present research work involves the development of an ANN model to measure the surface roughness and material removal rate in cylindrical grinding process of EN24 steel. The following conclusions are drawn from the analysis:
- Three software and computer-based techniques such as Taguchi DOE in MINITAB, ANN in MATLAB is successfully applied for the prediction of Ra and MRR.
- DOE with L_{16} orthogonal array provides sufficient data for process modeling without any compromise with quality of machining process and reduce the experimentation cost and time.
- The investigation indicates that the process parameters workpiece speed, feed rate and depth of cut are the primary influencing factors which affect thesurface roughness and MRR.

Future Scope

After completion of experimental work, analysis of process parameters, study of cylindrical grinding process and basic concepts of ANN possibilities for future work are as follows:

- The artificial neural network technique is not only for cylindrical grinding process it can also use for other machining processes.
- Only three parameters are considered in present work. The work can be extended by considering different parameters like grinding wheel speed, coolant flow rate, number of passes etc