Implementation of Google Studio and Taguchi DOE to minimize the Resultant Vibration in Hard Turning

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Abstract

The present investigation is related to the implementation of Google Studio and Taguchi DOE for parametric optimization of the turning process of hard AISI M2 grade material. The main aim of the present investigation was to minimize the resultant vibration during the turning process of AISI M2 on the CNC Machine. In this study, the whole experimentation has done in dry conditions. The process parameters selected for the investigation was Cutting Speed, Feed Rate, Depth of Cut, and resultant vibration selected as quality response characteristic. The material AISI M2 hardness during experimentation was 62-64 HRC. This hardness is selected for the study because this is the actual hardness of the drill tool. Google Studio is employed to generate results and data analysis. The MINITAB 21.2 software is used to design the experiment. The turning process optimization is done using Taguchi Method and Google studio. It is concluded that the feed rate is the most significant machining parameter which affects the resultant vibration signal. The optimum level of process parameters is cutting speed= 180 mm/min, feed rate= 0.1 mm/rev, and depth of cut = 0.4 mm.

Key Words: Google Studio, Taguchi DOE, AISI M2, ANOVA, Resultant Vibration.

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1. INTRODUCTION

In today's world, a great deal of attention is placed on investigating vibration signals in various machining operations, such as drilling, milling, turning, and so on. Studying and optimizing the resultant tool vibration signals in the machining process is very important. This is because minimizing the resultant vibration signal allows us to obtain various benefits, such as the minimum possible tool wear, a better surface finish, increased tool life, and increased productivity due to the minimum setting time for the machine. Because of these benefits, it is very important to minimize the resultant vibration signal.

Abouelatta, O. B. et al. [1], "employed an FFT analyzer to measure tool vibration in the radial direction and feed direction and for measurement of surface roughness the Surtronic 3+ measuring instrument used and correlation between surface roughness and cutting vibration during turning established. They developed a mathematical model for the predicted roughness parameter based on the cutting parameter and machine tool vibration for a better understanding of the relation. Finally, the measured results were analyzed by commercial software MATLAB, BC++, and SPSS."

Bhuiyan. M. S. H. et al. [2], "investigated various sensors used to monitor tool conditions using optical, electrical, and magnetic signals. They studied transient elastic waves generated during machining known as acoustic emission (AE). They proposed the use of an acoustic emission sensor and tri-axial accelerometer placed on a shank of the cutting tool holder was capable to monitor tool condition. The acoustic emission sensor assessed the internal change whereas the vibration sensor asses' the external information of the tool state. They illustrated the use of RMS signal and fast Fourier transform as the output of the sensor. They proved that vibration components, Vx, Vy, and Vz change with feed rate, depth of cut, and cutting speed respectively. The amplitude of vibration components decreases with the increase of cutting speed and increases with the increase of feed rate and depth of cut."

Alonso, F. J., and Salgado, D. R. [3], "developed a reliable tool condition monitoring system (TCMS) for industrial application. They employed singular spectrum analysis (SSA) and cluster analysis for analysis of the tool vibration signals. SSA was a non-parametric technique, of time series analysis that decomposes the acquired tool vibration signals, and Cluster analysis was used to group the SSA decomposition in order to obtain several independent components in the frequency domain that are applied to feed-forward back-propagation (FFBP) neural network to determine the tool flank wear."

Aliustaoglu, C. et al. [4], "studied tool wear condition monitoring using a sensor fusion model based on a fuzzy inference system. They mainly concentrated on the drilling and milling operation. They used two-stage fuzzy logic schemes for developing the advanced tool condition monitoring system. They acquired signals from various sensors and processed them to decide the status of the tool. In the first stage, they derived statistical parameters from thrust force, machine sound (acquired via a very sensitive microphone), and vibration signals were used as inputs to the fuzzy process; the crisp output values of this process were then taken as the input parameters of the second stage. Conclusively, outputs of this stage were taken into a threshold function, the output of which was used to assess the condition of the tool."

Bhuiyan, M. S. H. et al. [5], "studied the tool wear, chip formation, and surface roughness of workpieces under different cutting conditions in machining using acoustic emission (AE) and vibration signature in turning. The investigation concluded that the acoustic emission and vibration components can effectively respond to different occurrences in turning including tool wear and surface roughness. The acoustic emission has shown a very significant response to tool wear progression whereas resultant vibration (V) represented surface roughness in turning. Vibration components Vx, Vy, and Vz described the chip formation type and increase with the increase of feed rate, depth of cut, and cutting speed respectively. A KISTLER 8152B AE-piezoelectric sensor with a sensitivity of 57 dB ref 1 V/(m/s) and a KISTLER 8762A50 tri-axial accelerometer with a sensitivity of 100 ± 5% mV/g were used. They captured raw acoustic emission and vibration sensors analyzed to determine the different occurrences, including the tool wear and surface roughness of the workpiece. The data from direct measurement of flank wear and surface roughness, and chip formation occurrences were utilized to justify the signals response, and thus to investigate the tool condition even more accurately. The output signals from the acoustic emission and vibration sensors were essentially complex and stochastic in nature. The acoustic emission and vibration signature performed exceptionally well to investigate the tool state and the different turning occurrences. The combined application of acoustic emission and vibration sensors described the tool wear, tool breakage, chip formation, chip breakage, machine tool vibration, machine vibration, and workpiece surface roughness."

Kilundu, B. et al. [6], "presented the singular spectrum analysis (SSA) for the analysis of vibration signal from the tool holder. They explored the use of data mining techniques for tool condition monitoring in metal cutting. They also performed Pseudo-local singular spectrum analysis (SSA) on vibration signals measured on the tool holder. Then this is coupled to a band-pass filter to allow the definition and extraction of features that are sensitive to tool wear. These features are defined in some frequency bands, from sums of Fourier coefficients of reconstructed and residual signals obtained by SSA. They also studied two important aspects the strong relevance of information in high-frequency vibration components and the benefits of the combination of SSA and band-pass filtering to get rid of useless components (noise)."

Abuthakeer, S. S. et al. [7], "used a damping pad made from neoprene to control the cutting tool vibration. The experiment was carried out in fewer than two cases with the use of a damping pad and without a damping pad on the CNC LATHE machine. They developed an empirical model using analysis of variance (ANOVA). They also used a multilayer perception neural network model constructed feed-forward back-propagation algorithm using the acquired data. On the completion of the experimental test, ANN was used to validate the results obtained and also to predict the behavior of the system under any cutting condition within the operating range."

Krupal Pawar et al. [12] "investigated the effect of insert nose radius and machining parameters including cutting speed, feed rate, and depth of cut on surface roughness (Ra) and material removal rate (MRR) in a turning of HSS (M2) using the Taguchi method and ANOVA. A three-level, four-parameters design of experiment, L9 orthogonal array using Minitab 14 software, the signal-to-noise (S/N) ratio is employed to study the performance characteristics in the turning of HSS (M2) by taking the nose radius of Tin coated carbide inserts tool of 0.4, 0.8 and 1.2 mm on CNC turning centre. The analysis of variance (ANOVA) is applied to study the percentage contribution of each machining parameter while CNC turning of HSS (M2) material. All experimental trials are conducted in dry machining environment and at a constant spindle speed of 2800 rpm. The results are verified by taking confirmation experiments. The present investigation indicates that feed rate and nose radius are the most significant factors in the case of material removal rate and surface roughness for turning HSS (M2) material."

By studying various papers, it is concluded that no work is found for optimizing the resultant vibration for hard (62-64 HRC) AISI M2 using Google studio and Taguchi DOE with help of MINITAB 21.2. This investigation demonstrates details of the Taguchi optimization technique to optimize the resultant vibration signal during hard turning. The main objective of the present study is to find out set machining parameters which result in minimum resultant vibration signal in Hertz while turning hard AISI M2 on a CNC machine.

2. EXPERIMENTATION SETUP AND CUTTING CONDITIONS

For the conducting experimental trials, the ACE make CNC model Simple Turn-5075 Siemens 802C is employed (see Fig.2). First of all, it is very important to select a process with process parameters and their levels. In the research work, machining parameters such as cutting speed, feed rate, and depth of cut are selected for optimization of resultant vibration. The three parameters with three levels are fixed with the help of the insert manual and machining handbook (see Table.1). In the present research work, we are going to utilize the Taguchi method for experiment design. The design of the experiment is done with help of MINITAB 21.2 software and for this condition suited orthogonal array such as L27 is selected from the series of arrays. The design of experimental trials is shown in Table 2.

Table 1. Control Factors with Levels

Levels	Control Parameters		
	Cutting Speed (mm/min)	Feed Rate (mm/rev)	Depth of Cut (mm)
L1	100	0.1	0.4
L2	140	0.15	0.5
L3	180	0.2	0.6

The AISI M2 material rods with 60 mm diameter and 350 mm length are selected for experimental trials. The chemical analysis of AISI M2 material C-0.86/0.96, Cr-3.8/4.5, Mo-4.9/5.5, W-6.0/6.75, V-1.7/2.2[10] and the properties of AISI M2 are density-8.028×10-3g/mm3, melting point-46800, hardness-62-65 HRC, compressive yield strength-3250 Mpa, Poisson's ratio-0.27-0.30, elastic modulus-190-210 Gpa [10]. In the present work, a rectangular shape PCBN CNMG 160408 insert (Kennametal company) is used as a cutting tool used for turning hard AISI M2 specimens. The clearance angle of the selected insert is zero. The inscribed circle size is 9.5mm and the thickness is 5mm. A tool holder such as PCLNR 2525M12 is employed to hold the insert.

After DOE, it is important to conduct all trials as per the design of the experiment. The RT-Pro photon software is first installed in the laptop to support the FFT analyzer. The vibration signal frequency in three directions (Vx, Vy, and Vz) are measured using an FFT analyzer with a three-axis accelerometer and after measuring signals, the resultant vibration signals are calculated and inserted in the already design of experiment table in MINITAB 21.2 software. After inserting resultant vibration signals in the MINITAB 21.2 software, the signal-to-noise ratios for each trial is calculated by applying the smaller is better condition.

$$S/N = -10 \times log(\Sigma(Y^2)/n) \quad (1)$$

Where, S/N-Signal to Noise Ratio, Yi – ith observed value of the response, n - Number of observations in a trial, Y - Average of observed responses values.

Figure 2. Experimental Unit

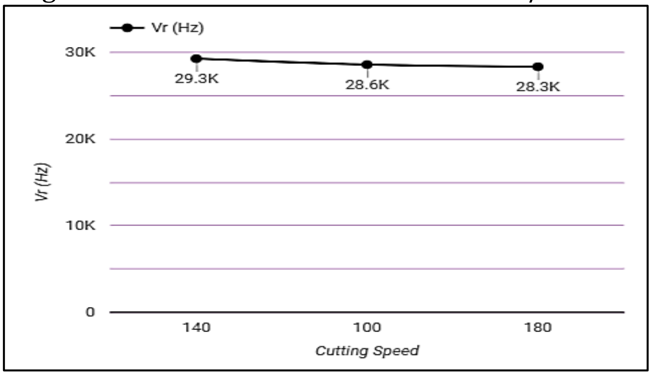
Table 2. Experiment Conduction as DOE

Exp. No.	Cutting Speed	Feed Rate	Depth of Cut	Vr (Hz)	S/N Ratio (dB)
1	100	0.1	0.4	2744.52	-69.08
2	100	0.1	0.5	3343.94	-70.74
3	100	0.1	0.6	2666.56	-68.84
4	100	0.15	0.4	3325.41	-70.69
5	100	0.15	0.5	3301.44	-70.63
6	100	0.15	0.6	3349.09	-70.75
7	100	0.2	0.4	3308.10	-70.65
8	100	0.2	0.5	3305.21	-70.64
9	100	0.2	0.6	3239.84	-70.47
10	140	0.1	0.4	3335.84	-70.72
11	140	0.1	0.5	3266.57	-70.54
12	140	0.1	0.6	3264.80	-70.54
13	140	0.15	0.4	3329.06	-70.70
14	140	0.15	0.5	3327.28	-70.70
15	140	0.15	0.6	3323.36	-70.69
16	140	0.2	0.4	2766.92	-69.15
17	140	0.2	0.5	3326.14	-70.70
18	140	0.2	0.6	3333.62	-70.72
19	180	0.1	0.4	2547.98	-68.46
20	180	0.1	0.5	3162.74	-70.27
21	180	0.1	0.6	2710.94	-68.98
22	180	0.15	0.4	3439.86	-70.73
23	180	0.15	0.5	2827.03	-69.03
24	180	0.15	0.6	3421.24	-70.68
25	180	0.2	0.4	3450.82	-70.76
26	180	0.2	0.5	3389.91	-70.60
27	180	0.2	0.6	3386.19	-70.59

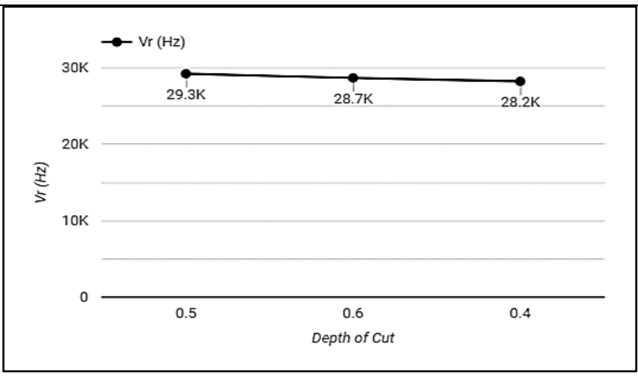
The calculation of signal-to-noise ratios with help of MINITAB 21.2 software is shown in the following Table 2.

3. RESULTS AND DISCUSSION

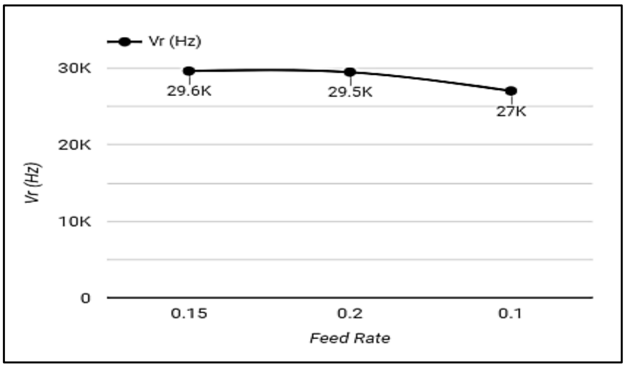
Figure 3. indicates the evolution of the resultant vibration signal according to the three machining parameters. Figure 3. shows that the resultant vibration signal is minimum at a cutting speed of 180 mm/min. It shows that at a cutting speed of 180 mm/min, the resultant vibration signal is at an optimum level means we will get a smooth operation with minimum resultant vibration at 180 mm/min. The feed rate is the most influencing factor for the resultant vibration signal. The resultant vibration at 0.1 mm/rev is at the minimum stage.



(a) Resultant Vibration (Vr) vs Cutting Speed



(b) Resultant Vibration (Vr) vs Depth of Cut



(c)Resultant Vibration (Vr) vs Feed Rate

Figure 3. Plots using Google Studio for Resultant Vibration Vs. Machining Parameters (i.e. Cutting Speed, Depth of Cut, and Feed Rate)

6. CONCLUSION

It is concluded that for turning the hard AISI M2 tool steel, the feed rate is the more important machining parameter that affects the resultant vibration signal. The optimum level of process parameters is cutting speed= 180 mm/min, feed rate= 0.1 mm/rev, and depth of cut = 0.4 mm at which we get the minimum resultant vibration. In this research, we have implemented Google Studio for data visualization. Google Studio is the best tool for data visualization, filtering, and clearing data.

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