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Research Article

Experimental Investigation of Machine Tool Vibration in SS 304 Turning

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Abstract

Passive damping is now the major means of suppressing unwanted vibrations. In the present work, attempt is made to predict and suppress the vibration level of cutting tool in CNC lathe, by using passive damping pad of Viscoelastic material S20. The effects of damping pad and cutting parameters on machine tool vibration were experimentally investigated. The experimentation is carried out on CNC lathe for dry turning of SS304 work piece material using single point carbide tool inserts of varying tool nose radius. Three levels for spindle speed, depth of cut, feed rate and tool nose radius were chosen as cutting variables. Design of Experiment (DOE) approach is selected for investigating the effect of varying controllable parameters on Tangential acceleration. The Taguchi method L_{27} orthogonal array was applied to design of experiment. This research work highlights the influence of cutting parameters on the tool vibration during machining using and optimizes the multi response parameters on turning operation using Taguchi Method and Regression Analysis.

Keywords: *Transverse machine tool vibration; passive damping; ANOVA, Cutting Parameters, Taguchi Method.*

1. Introduction

In turning operation, tool vibration is a common problem and it affects the performance of a machine, tool life and surface finish of the work material. The standard procedure adopted to avoid vibration during machining is by careful planning of the cutting parameters and damping of cutting tool.

There have been many investigations on vibration prediction and control in turning. The cutting-force based vibration analysis can be done to ascertain the effect of the tool entering angle on tool vibration and tool life in a titanium alloy milling operation (A. I. Sette, *et.al*, 2010).The main purpose behind this analysis is to decrease the vibration of the cutting tool in the milling process of Ti–6Al–4V.The vibration analysis test is carried out using a piezoelectric accelerometer and an instrumented hammer with a 200 force transducer to identify the transfer function in a broad range of frequencies. Samples were recorded at 20 kHz. A stationary dynamometer, a National Instruments PCI-6025E analogical/digital data acquisition board and LabVIEWs 8.5 software were used for 3-axis cutting force measurements. The signals were processed with Matlab 7.1 software. The tool life and wear pattern were correlated to tool vibration. It was concluded that for a productive milling operation on Ti–6Al–4V alloy and a long tool life require minimum tool vibration. To get the optimum tool life, the reliability estimation of cutting tools based on a logistic regression model can be developed using vibration signals (B. Chen, *et.al*, 2011). The vibration signals of carbide tool are monitored with the help of accelerometer and these signals then send to data acquisition system and a portable computer. The main purpose of this vibration analysis is to find the features revealing tool wear. Wavelet Packet decomposition is used to find out feature frequency band which reveals tool wear. The high degree of correlation between selected band energy, energy entropy, time-domain features and tool wear are observed. Hence, it shows the effectiveness of the proposed model that facilitates machine performance and reliability estimation in terms of tool life and tool wear.

The excessive wear on cutting tools leads to distortions in dimension of manufactured components. At the same time it increases scrapped levels thereby incurring additional costs. Therefore, it is crucial to detect and monitor the wear on a cutting tool in most metal cutting processes and several research efforts have done to develop on-line tool condition monitoring systems. In online metal cutting tool condition monitoring, the cutting force (Static and Dynamic) analysis and vibration analysis is done for tool wear monitoring (D. E. Dimla *et.al*, 2000). The main purpose of this study was to develop a Tool Condition Monitoring System based on analytical modelling of online sensor signals. The results shows that the cutting forces in Z-direction and the vibration signatures were most sensitive to tool wear.

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In manufacturing industries, the surface roughness plays an important role while manufacturing the mechanical components like gears, bearings etc. To meet the predetermined geometrical fits and tolerances, it is important to obtain minimum surface roughness values. Hence, the theoretical and experimental investigation is done to find out the influence of tool-tip vibration on surface generation in single point diamond turning (H. Wang *et.al*, 2010). The result shows that the tool-tip vibration and the process damping effect are regarded as the prime influences on surface roughness. To the study the surface roughness in the Wire Electric Discharge Machining (WEDM) of AISI D3 Steel, an orthogonal array, the signal-to-noise (S/N) ratio and the analysis of variance (ANOVA) were employed (B. K. Lodhi *et.al*, 2014). The aim was to obtain the optimum machining conditions for WEDM of AISI D3 steel, for minimizing the surface roughness based on Taguchi technique. Experiments are carried out to study the effect of various parameters viz. pulse peak current, pulse on time, pulse off time, and wire feed, on the surface finish. The levels of significance on the surface roughness were statistically evaluated by using analysis of variance (ANOVA) and optimized the machining conditions for surface roughness based on (L9 Orthogonal Array) Taguchi methodology.

Experimental work was carried out under varying pulse-on-time, pulse-off-time, peak current, and wire feed. It was observed that the discharge current was the most influential factors on the surface roughness. To validate the work, experimentation has been carried out at optimum set of parameters and predicted results have been found. It shows that the predicted results are in close approximation with experimental output and the error associated with surface roughness is only 3.042 %.

As the vibrations of the machine-tool structure and the tool-workpiece interaction are the main contributors to the tool vibration, a new Kalman estimator-based feed-forward control scheme was developed and employed to minimize the vibration transmitted to the tool through the machine-tool structure (A. H. El-Sinawi *et.al*, 2005). The transmitted force enables the successful isolation of the tool from the vibration of the machine-tool structure improving the surface finish of turned workpiece. The vibrations of structures submitted to human loadings can be minimized by using the damping treatments. An integrated vibration avoidance and contouring error compensation algorithm is used for multi-axis CNC machine tools (Y. Altintas *et.al*, 2012). They developed an integrated method which shapes the trajectory commands in such a way that they do not excite the structural modes.

Based on active and passive damping treatments, different models are developed to avoid the machine-tool structure vibrations. A computational–theoretical model was developed to represent a structural system with Coulomb damping having two degrees of freedom (M. A. Louroza *et.al*, 2005). Approximately 85 percent of the passive damping treatments in actual applications are based on viscoelastic materials (S. S. Abuthakeer *et.al.*, 2011). He worked on the cutting tool vibrations and control of cutting tool vibration using a damping pad made up of neoprene. Experimental trials were conducted on CNC lathe when the tool holder is supported with and without damping pad. The vibration signals were collected through a data acquisition system supported by Lab VIEW software. The reliability of the experiment was increased by full factorial experimental design. The data obtained from experimentation have been analyzed to validate the proposed damping system. The online tests show that the proposed system reduced the vibrations of cutting tool to a greater extend. The vibration analysis was done without any damping pad under actual machining conditions. From this literature review of machine tool vibration it is observed that the passive damping is the major means of suppressing unwanted vibrations.

In the present work attempt has been made to predict and suppressing the transverse vibration level of cutting tool in CNC lathe for dry turning of SS304, by using passive damping pad of viscoelastic material S-20. These vibrations are minimized by controlling the cause parameter and suppressing peak acceleration by using passive damping method.

2 Methodology

Design of Experiment approach is selected for investigating the effect of varying controllable parameters on tangential acceleration. Numbers of experiments to be performed are decided with the help of Taguchi Method with MINITAB 15 software. It is assume that inherent vibration, tool wear and L/D are constant throughout experimentation and tool nose radius, cutting Speed, depth of cut and feed rate are varied at different levels. The present work shows the influence of cutting parameters on the transverse tool vibration during machining. Here, optimization of cutting parameters and tool parameters on turning are carried out by Taguchi Method, Regression Analysis and ANOVA. The number of levels considered for each factor in DOE is as shown in Table 1.

Table 1 Machining Parameters and Their Levels

Parameters	Level 1	Level 2	Level 3
Spindle speed (rpm) X1	420	520	620
Depth of cut (mm) X2	0.4	0.5	0.6
Feed rate(mm/rev) X3	0.15	0.2	0.25

As the number of experiments are too much in full factorial design which involves more machining time and more cost of operation. The DOE is applied using Taguchi design to get an optimal number of experiments by using orthogonal array. The Taguchi method L_{27} orthogonal array for four factors with three levels is applied to design of experiments.

3 Experimentation

Main objective of this paper is to monitor the vibration level of cutting tool assuming the condition of a machine and its components is good in all other aspects such as foundation stiffness and rigidity of the machine components like bed, spindle, tail stock etc. For the machine tool vibration analysis, Root Mean Square (RMS) values of tangential acceleration are recorded with the help of FFT analyzer. The experimental setup consists of CNC lathe machine and FFT analyzer. The experimental setup is shown in Fig.1.

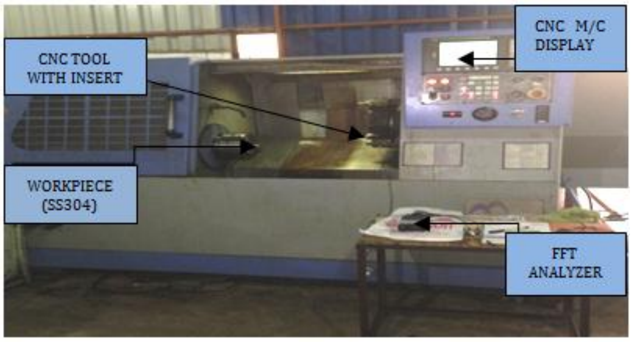


Fig.1 Experimental setup of CNC Lathe Turning Operation

It consists of a CNC-MIDAS-0 turning center, tool insert TNMG 160404, SS304 workpiece of 32 mm diameter with 30 mm length and FFT analyzer with tri-axial accelerometer, SV 84. Vibration signals are important for monitoring tool condition in turning process. Accelerometer is mounted on the cutting tool that measures the vibration amplitude in terms of accelerations (g-levels) for tangential direction of the tool holder. Fast Fourier Transform (FFT) computation algorithm was included in the computer program to extract the vibration amplitude in the time and frequency domain. For experiment purpose three tungsten carbide inserts of triangular shape having tool nose radius 0.4 mm, 0.8 mm and 1.2 mm are used, manufactured by Sandvik Asia Pvt. Ltd. Specification of tool insert is

1. TNMG 160404-61 having grade no. 4225.
2. TNMG 160408-61 having grade no. 4015.
3. TNMG 160412-61 having grade no. 4215.

SS 304 of diameter 32 mm is selected as a workpiece material for the experiment. The chemical composition and mechanical properties of SS304 are shown in Table 2 and Table 3.

Table 2 Chemical Composition of SS 304

Grade	C (%)	Mn (%)	Si (%)	P (%)	S (%)	Cr (%)	Ni (%)	N (%)
SS 304	0.08 Max	2.0	0.75	0.045	0.030	18-20	8-10.5	0.1

Table 3 Mechanical Properties of SS 304

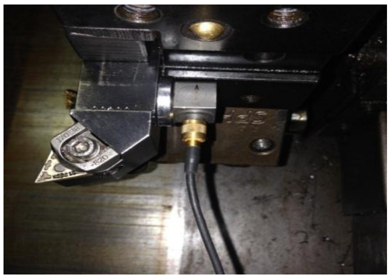
Grade	Tensile strength (Mpa)	Yield Strength 0.2% Proof (Mpa) min	Elongation (% in 50 mm) Min	Rockwell B (HR B) max	Brinell (HB) max
SS 304	515	2.0	0.75	0.045	0.030

S-20 is used as a damper material. Detail properties of damping material are given below in tabulated form as shown in Table 4.

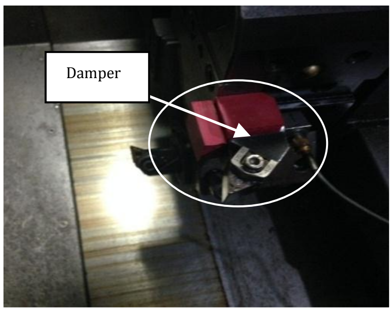
Table 4 Properties of S-20 Damper

Sr. No.	Material Properties	S 20
1	Hardness	60-55 BHN
2	Temperature	-40 to 85 deg
3	Thermal Conductivity	-
4	Tensile Strength	0.13789 MPa
5	Tear Strength	0.01034 MPa

Design of Experiment (DOE) approach is selected for investigation effect of varying controllable parameter on tangential acceleration as 27 runs are selected for Taguchi design to study the effect of two or more factors in three levels. The factors are referred as low level, intermediate level & high level. For the present work the amplitude of transverse vibration in terms of acceleration (g-level) is measured with and without damping pad. Tool without damper and with S-20 damper is shown in Fig. 2.



(a) Without Damper



(b) With S-20 Damper

Fig. 2 (a), (b) Machine-tool without damper and with S-20 damper

The observations are recorded for the amplitude of transverse vibration of cutting tool in terms of acceleration (g- level) as shown in Table 5 for S-20 damper.

Table 5 Observations recorded for Amplitude of acceleration in tangential direction for S-20 Damper

SR. No.	Nose Radius (mm)	Spindle Speed (rpm)	Depth of Cut (mm)	Feed Rate (mm/rev)	Amplitude of Acceleration of cutting tool in g Tangential Direction (RMS)	
					Without Damper	With Damper
1	0.4	420	0.4	0.15	2.44	2.10
2	0.4	420	0.4	0.15	2.62	1.70
3	0.4	420	0.4	0.15	2.89	1.90
4	0.4	520	0.5	0.2	4.45	2.23
5	0.4	520	0.5	0.2	4.29	3.60
6	0.4	520	0.5	0.2	5.36	2.97
7	0.4	620	0.6	0.25	7.47	6.50
8	0.4	620	0.6	0.25	7.30	5.60
9	0.4	620	0.6	0.25	8.05	5.87
10	0.8	420	0.5	0.25	6.36	3.39
11	0.8	420	0.5	0.25	6.37	3.37
12	0.8	420	0.5	0.25	6.21	3.12
13	0.8	520	0.6	0.15	9.80	4.14
14	0.8	520	0.6	0.15	10.50	4.60
15	0.8	520	0.6	0.15	10.10	4.34
16	0.8	620	0.4	0.2	7.60	4.97
17	0.8	620	0.4	0.2	7.22	5.30
18	0.8	620	0.4	0.2	7.27	5.82
19	1.2	420	0.6	0.2	4.39	2.43
20	1.2	420	0.6	0.2	4.20	2.51
21	1.2	420	0.6	0.2	2.07	2.06
22	1.2	520	0.4	0.25	2.93	2.92
23	1.2	520	0.4	0.25	3.01	2.90
24	1.2	520	0.4	0.25	3.14	2.89
25	1.2	620	0.5	0.15	4.50	4.08
26	1.2	620	0.5	0.15	4.17	4.11
27	1.2	620	0.5	0.15	4.23	4.16

4. Results and Discussion

Based on the experimental results, the statistical analysis software system MINITAB 15 is used for linear regression analysis of damped and undamped condition. A regression equation is developed for each desired output. The regression coefficients are estimated by regression analysis.

The regression equation for tangential acceleration without damper is obtained as follows:

Tangential Acceleration =4.120833 NR + 0.023672 SS + 6.727778 DoC + 11.2333 FR - 9.6553 (1)

Where NR is nose radius in mm, SS is spindle speed in rpm, DoC is depth of cut in mm and FR is feed rate in mm/rev.

Table 6 Regression for Tangential Acceleration without damper

Regression Statistics				
Multiple R	R Square	Adjusted R Square	Standard Error	Observations
0.8533	0.7282	0.6788	1.665	27

Table 6 shows the regression analysis for tangential acceleration without damper. The value of adjusted R square is 67.88 % and is a decrease of 4.94 % R square value indicate that the degree of closeness of variable with best fit line. The value of R square which is 0.7282 indicates that the degree of closeness of the parameters with the best fitted line is 72.82 %. It shows that the parameters are correlated with each other.

ANOVA Analysis: Vibration data values are analyzed using Analysis of Variance (ANOVA) to study the influences of the cutting parameters on transverse vibration. The cutting parameters such as depth of cut, feed rate, and spindle speed are considered as input for transverse vibration and tangential acceleration is considered as output parameter.

In the ANOVA results, F-test values are used at 95% confidence level to decide the significant factors affecting the machine tool vibration and percentage contribution. As per ANOVA analysis, for a particular cutting parameter the P value less than 0.05 (5%) and larger F value indicates that the statistically significant effects on the machine tool vibration in tangential direction. The ANOVA results of machine tool vibration without damping for Taguchi design are as shown in Table 7(a) and Table 7(b):

Table 7 (a) ANOVA of Tangential Acceleration without damper

	df	SS	MS	F	Significance F
Regression	4	163.599	40.899	14.741	5.37E-06
Residual	22	61.039	2.774		
Total	26	224.638			

The Table 7 (a) and (b) of ANOVA shows the degrees of freedom (df), sum of squares (SS), mean squares (MS), F-value (F) and P values. It shows that the F value is 14.741; this indicates that the obtained trials are considered to be statistically significant. It demonstrates that the cutting parameters used for the model have a significant effect on the tangential acceleration.

Table 7 (b) ANOVA for Tangential Acceleration without damper

Predictor	Coeff.	Standard Error	t Stat	P-value	Significance
Intercept	-9.655	3.347	-2.884	0.0086	Significant
X Variable 1	4.121	0.981	4.198	0.0003	Significant
X Variable 2	0.023	0.003	6.029	4.55E-06	Significant
X Variable 3	6.727	3.926	1.713	0.1006	Not Significant
X Variable 4	-11.233	7.852	-1.430	0.1665	Not Significant

In Table 7(b), X variable 1 represents tool nose radius in mm, X variable 2 represents spindle speed in rpm, X variable 3 represents depth of cut in mm and X variable 4 represents feed rate in mm/rev. A low P-value (≤0.05) indicates statistical significance for the source on the corresponding response that is α = 0.05, or 95% confidence level.

From Table 7(b), it is concluded that the tool nose radius and spindle speed are the most significant parameters for machine tool vibration in tangential direction whereas depth of cut and feed rate are insignificant parameters which does not contribute the machine tool vibration.

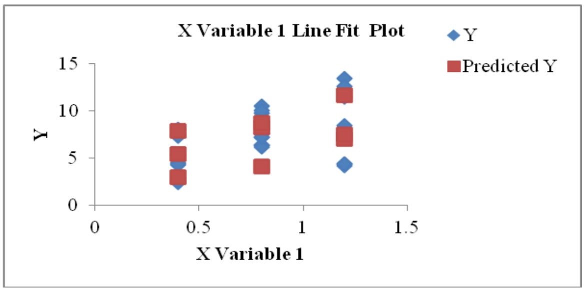
The results obtained for predicted acceleration and residual outputs without damping are shown in Table 8 where predicted Y represents the tangential acceleration in without damping condition.

Table 8 Predicted Results of Tangential Acceleration without damping

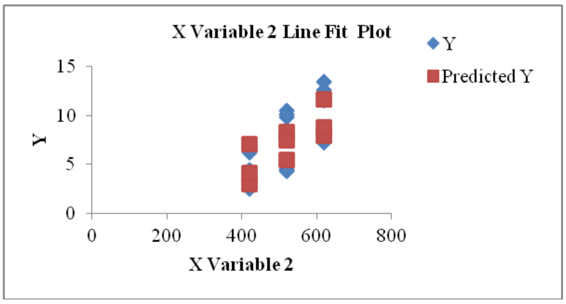
Observation	Predicted Y	Residuals
1	2.941481	-0.501481481
2	2.941481	-0.321481481
3	2.941481	-0.051481481
4	5.419815	-0.969814815
5	5.419815	-1.129814815
6	5.419815	-0.059814815
7	7.898148	-0.428148148
8	7.898148	-0.598148148
9	7.898148	0.151851852
10	4.139259	2.220740741
11	4.139259	2.230740741
12	4.139259	2.070740741
13	8.302593	1.497407407
14	8.302593	2.197407407
15	8.302593	1.797407407
16	8.762593	-1.162592593
17	8.762593	-1.542592593
18	8.762593	-1.492592593
19	7.022037	-2.632037037
20	7.022037	-2.822037037
21	2.941481	-0.501481481
22	2.941481	-0.321481481
23	2.941481	-0.051481481
24	5.419815	-0.969814815
25	5.419815	-1.129814815
26	5.419815	-0.059814815
27	7.898148	-0.428148148

A line fit plot is obtained to verify that whether model obtained is statically significant or not. Fig. 4 shows the line fit plot for experimental acceleration and predicted acceleration without damping. Here X variable 1 represents tool nose radius in mm, X variable 2 represents spindle speed in rpm, X variable 3 represents depth of cut in mm and X variable 4 represents feed rate in mm/rev. The parameter Y represents experimental tangential acceleration whereas predicted Y represents predicted tangential acceleration.

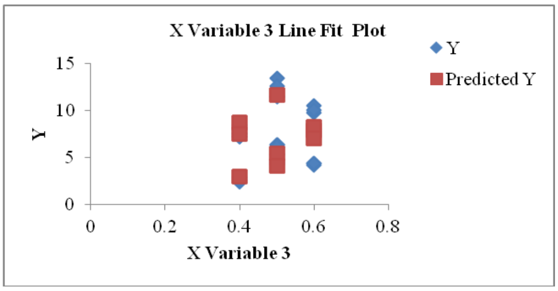
Fig. 3(a), (b), (c) and (d) shows the Comparison of Experimental and Predicted values of Tangential Acceleration for (NS, SS, Doc and FR) Without Damping



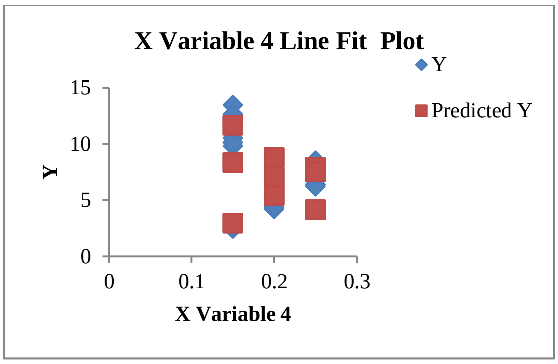
(a) Experimental vs. Predicted values of Tangential Acceleration at tool nose radius range of 0.4mm to 1.2 mm



(b) Experimental vs. Predicted values of Tangential Acceleration at spindle speed range of 420 rpm to 620 rpm



(c) Experimental vs. Predicted values of Tangential Acceleration at depth of cut range of 0.4 mm to 0.6 mm



(d) Experimental vs. Predicted values of Tangential Acceleration at feed rate range of 0.15 mm/rev to 0.25 mm/rev

Fig. 3(a) shows the comparison between experimental and predicted values of tangential acceleration without damping at X variable 1 called tool nose radius. From this it is observed that within the range of 0.4 mm to 1.2 mm, the predicted and experimental values of tangential acceleration are close to each other. Fig. 3(b) shows the comparison between experimental and predicted values of tangential acceleration without damping at X variable 2 called spindle speed. From this it is observed that within range of 420 rpm to 620 rpm, the predicted and experimental values of tangential acceleration are close to each other. Fig. 3(c) shows the comparison between experimental and predicted values of tangential acceleration without damping at X variable 3 called depth of cut. From this it is observed that within range of 0.4 mm to 0.6 mm, the predicted and experimental values of tangential acceleration are close to each other. Fig. 3(d) shows the comparison between experimental and predicted values of tangential acceleration without damping at X variable 4 called feed rate. From this it is observed that within range of 0.15 mm/rev to 0.25 mm/rev, the predicted and experimental values of tangential acceleration are close to each other. Hence from the above results it is concluded that the model obtained is statistically significant.

Similarly, the regression analysis is done for with damping condition using the software MINITAB 15.The regression equation for tangential acceleration with S 20 damper is obtained as follows:

Tangential Acceleration =0.09722 NR + 0.09722 SS + 0.013211 DoC + 3.922222 FR - 6.25422 (2)

Where NR is nose radius in mm, SS is spindle speed in rpm, DoC is depth of cut in mm and FR is feed rate in mm/rev.

Table 9 Regression for Tangential Acceleration with S-20 Damper

Regression Statistics				
Multiple R	R Square	Adjusted R Square	Standard Error	Observations
0.8757	0.7669	0.7246	0.7070	27

Table 9 shows the regression analysis for tangential acceleration with S-20 damper. The value of adjusted R square is 72.46 % and is a decrease of 4.24 % R square value indicate that the degree of closeness of variable with best fit line. The value of R square which is 0.7669 indicates that the degree of closeness of the parameters with the best fitted line is 76.69 %. It shows that the parameters are correlated with each other.

The ANOVA results of machine tool vibration with S-20 damping for Taguchi design are as shown in Table 10(a) and Table 10(b):

Table 10 (a) ANOVA for Tangential Acceleration with S-20 Damper

	df	SS	MS	F	Significance F
Regression	4	36.192	9.048	18.100	1.04E-06
Residual	22	10.997	0.499		
Total	26	47.189			

The Table 10 (a) and (b) of ANOVA shows the degrees of freedom (df), sum of squares (SS), mean squares (MS), F-value (F) and P values. As the F value is 18.10, this indicates that the obtained trials are considered to be statistically significant. It demonstrates that the cutting parameters used for the trails have a significant effect on the tangential acceleration.

Table 10 (b) ANOVA for Tangential Acceleration with S-20 Damper

Predictor	Coefficient	Standard Error	t Stat	P-value	Significance
Intercept	-6.254	1.420	-4.401	0.0002	Significant
X Variable 1	-0.097	0.416	-0.233	0.8176	Not Significant
X Variable 2	0.013	0.001	7.927	6.86 E-08	Significant
X Variable 3	3.922	1.666	2.353	0.0279	Significant
X Variable 4	6.633	3.332	1.990	0.0591	Not Significant

In Table 10(b), X variable 1 represents tool nose radius in mm, X variable 2 represents spindle speed in rpm, X variable 3 represents depth of cut in mm and X variable 4 represents feed rate in mm/rev. A low P-value (≤0.05) indicates statistical significance for the source on the corresponding response that is $\alpha = 0.05$, or 95% confidence level.

From Table 10 (b), it is concluded that the spindle speed and depth of cut are the most significant parameters for machine tool vibration in tangential direction whereas tool nose radius and feed rate are non-significant parameters which do not contribute to the machine tool vibration.

The results obtained for predicted acceleration and residual outputs with S-20 damping are shown in Table 8 where predicted Y represents the tangential acceleration.

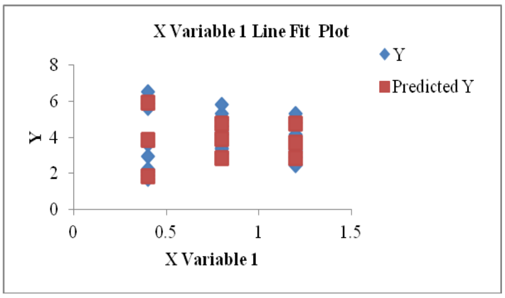
Table 8 Predicted Results of Tangential Acceleration for S-20 Damping

Observation	Predicted Y	Residuals
1	1.819444	0.280556
2	1.819444	-0.11944
3	1.819444	0.080556
4	3.864444	-1.63444
5	3.864444	-0.26444
6	3.864444	-0.89444
7	5.909444	0.590556
8	5.909444	-0.30944
9	5.909444	-0.03944
10	2.836111	0.553889

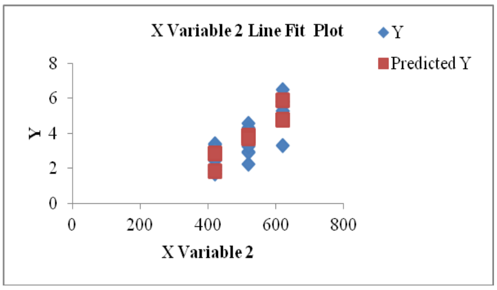
11	2.836111	0.533889
12	2.836111	0.283889
13	3.886111	0.253889
14	3.886111	0.713889
15	3.886111	0.453889
16	4.754444	0.215556
17	4.754444	0.545556
18	4.754444	1.065556
19	2.857778	-0.42778
20	2.857778	-0.34778
21	2.857778	0.292222
22	3.726111	-0.83611
23	3.726111	-0.47611
24	3.726111	0.423889
25	4.776111	0.023889
26	4.776111	-1.48611
27	4.776111	0.523889

A line fit plot is obtained to verify whether model obtained is statically significant or not. Fig. 5 shows the line fit plot for experimental acceleration and predicted acceleration with S 20 damping. Here X variable 1 represents tool nose radius in mm, X variable 2 represents spindle speed in rpm, X variable 3 represents depth of cut in mm and X variable 4 represents feed rate in mm/rev. The parameter Y represents experimental tangential acceleration whereas predicted Y represents predicted tangential acceleration.

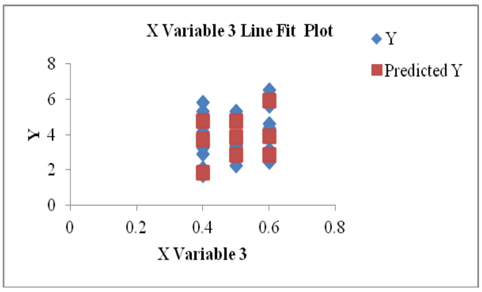
Fig. 4 (a), (b), (c) and (d) shows the Comparison of Experimental and Predicted values of Tangential Acceleration for (NS, SS, Doc and FR) with S-20 damping



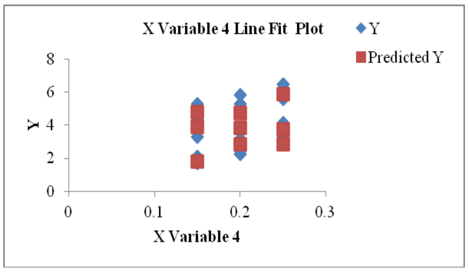
(a) Experimental vs. Predicted values of Tangential Acceleration at tool nose radius range of 0.4mm to 1.2 mm



(b) Experimental vs. Predicted values of Tangential Acceleration at spindle speed range of 420 rpm to 620 rpm



(c) Experimental vs. Predicted values of Tangential Acceleration at depth of cut range of 0.4 mm to 0.6 mm



(d) Experimental vs. Predicted values of Tangential Acceleration at feed rate range of 0.15 mm/rev to 0.25 mm/rev

Fig. 4(a) shows the comparison between experimental and predicted values of tangential acceleration with S 20 damping at X variable 1 tool nose radius. From this it is observed that within the range of 0.4 mm to 1.2 mm, the predicted and experimental values of tangential acceleration are close to each other. Fig. 4(b) shows the comparison between experimental and predicted values of tangential acceleration with S 20 damping at X variable 2 spindle speed. From this it is observed that within range of 420 rpm to 620 rpm, the predicted and experimental values of tangential acceleration are close to each other. Fig. 4(c) shows the comparison between experimental and predicted values of tangential acceleration with S 20 damping at X variable 3 depth of cut. From this it is observed that within range of 0.4 mm to 0.6 mm, the predicted and experimental values of tangential acceleration are close to each other. Fig. 4(d) shows the comparison between experimental and predicted values of tangential acceleration with S 20 damping at X variable 4 feed rate. From this it is observed that within range of 0.15 mm/rev to 0.25 mm/rev, the predicted and experimental values of tangential acceleration are close to each other.

Hence from the above results it is concluded that the model obtained is statistically significant.

Conclusions

The effect of cutting parameters such as nose radius of cutting tool, spindle speed, depth of cut and feed rate on machine tool vibration is evaluated.

From ANOVA shows that in undamped condition tool nose radius and spindle speed are the most influencing parameters for transverse machine tool vibration whereas for S-20 damping spindle speed and depth of cut are the most influencing parameters for transverse machine tool vibration.

Hence, spindle speed is the common factor in damped and undamped condition which influences transverse machine tool vibration.

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