IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

AN EXPERIMENTAL INVESTIGATION ON THE PERFORMANCE OF CUTTING TOOL UNDER VIBRATION BEHAVIOR WITH VARIABLE SYSTEM PARAMETERS

[1]Narendrakumar A. Patel, [2]Jeetendra A. Vadher

[1]Assistant Professor, [2]Professor and Head

[1]Mechanical Engineering Department, Government Engineering College, Palanpur, Gujarat, India,

Abstract: The performance of the cutting tool subjected to vibration depends upon the operational parameters of the systems. The experimentation is the most reliable means of investigating the vibrational behaviour of the cutting tool during the turning operation on work-piece. However, the empirical expressions developed based on the well-designed experimental observations give much reliable predictions. Hence, the core objective of the present study is to apply design of experiment (DOE) approach on the vibration study of cutting tool considering the four key variables: rotational speed (N) of the spindle i.e. work-piece, feed rate (f), depth of cut (DOC) (d_c) and the work-piece diameter (D). Based on the observations, the optimum parameter values identified are: N = 350 RPM, f = 0.15mm/rev, d_c = 0.3 mm and D = 40 mm. Moreover, the second order polynomial equation with cross-terms has been identified as the more suitable regression expression than the second and third order polynomial.

Keywords: *Tool Vibration, Regression Equation, Design of Experiment, ANOVA Model.*

I. INTRODUCTION

Machining vibrations, also called chatter, compare to the overall development between the work-piece and the cutting instrument. The vibrations bring about waves on the machined surface. This influences average machining measures, like turning, processing and penetrating, and abnormal machining measures, like pounding. A chatter mark is a sporadic surface defect avoided by a wheel that is with regards to valid in grinding or standard imprint left when turning a long piece on a machine, due to machining vibrations.

As right on time as 1907, Frederick W. Taylor[1] portrayed machining vibrations as the most dark and fragile of the multitude of issues confronting the mechanic, a perception actually obvious today, as demonstrated in numerous distributions on machining. The clarification of the machine device regenerative chatter was made by S. A. Tobias [2] also, W. Fishwick in 1958[2], by displaying the input circle between the metal cutting cycle and the machine device structure, and accompanied the strength projections chart. The design firmness, damping proportion and the machining cycle damping factor, are the principle boundaries that characterizes the breaking point where the machining interaction vibration is inclined to develop with time[3]. The numerical models make it conceivable to reproduce machining vibration precisely; yet practically speaking it is consistently hard to keep away from vibrations[4].

The utilization of rapid machining (HSM) has empowered an increment in profitability and the acknowledgment of work-pieces that were inconceivable previously, like flimsy walled parts[5]. Tragically, machine focuses are less robust a result of the great powerful developments. In numerous applications, for example long instruments, meager work-pieces, the presence of vibrations is the most restricting element and urges the engineer to decrease cutting velocities and feeds well underneath the limits of machines or devices[6].

Vibration issues by and large outcome in commotion, awful surface quality and in some cases device breakage[7]. The fundamental sources are of two sorts: constrained vibrations and self-created vibrations. Constrained vibrations are mostly created by intruded on cutting (innate to processing), run-out, or vibrations from outside the machine. Self-created vibrations are identified with the way that the real chip thickness relies likewise upon the overall situation among instrument and work-piece during the past tooth section[8]. In this way expanding vibrations may show up to levels which can truly corrupt the machined surface quality.

The standard strategy for setting up a machining interaction is still basically dependent on chronicled specialized skill and on experimentation technique to decide the best boundaries[9]. As per the specific abilities of an organization, different boundaries are concentrated in need, like profundity of cut, device way, work-piece set-up, and mathematical meaning of the instrument[10]. At the point when a vibration issue happens, data is typically looked for from the instrument producer or the CAM (Computer-helped fabricating) programming retailer, and they may give a superior technique for machining the work-piece[11]. Now and again, when vibration issues are an over the top monetary bias, specialists can be called upon to recommend, after estimation and computation, axle velocities or instrument changes[12].

Contrasted with the mechanical stakes, business arrangements are uncommon. To examine the issues and to propose arrangements, just couple of specialists proposes their administrations[13]. Computational programming for solidness projections and estimation gadgets are proposed however, notwithstanding boundless exposure, they remain generally infrequently utilized[14]. Ultimately, vibration sensors are frequently incorporated into machining focuses however they are utilized mostly for wear finding of the apparatuses or the axle. New Generation Tool Holders and particularly the Hydraulic Expansion Tool Holders limit the unwanted impacts of vibration generally[15]. As a matter of first importance, the exact control of absolute pointer perusing to fewer than 3 micrometers decreases vibrations because of adjusted burden on front lines and the little vibration made subsequently is assimilated generally by the oil inside the offices of the Hydraulic Expansion Tool Holder.

From the past study it is found that vibration during turning operation is major issue, it crate high chatter noise, poor surface finish, high tool wear, and also sometime damage to the tool or work piece. From the literature study following research gap has been found. Very few works have been carried out for vibration in three axes.Very less work carried out for the optimization of the parameter for the vibration. Moreover, very few literatures give corrective action on parameter based on the optimization. Further, the most literature focuses on the analysis of the vibration by simplifying in beam so real analysis not been analyzed. Furthermore, very few work carried out from the experimental work. Based on the mentioned research gap, the prime objective of the present study is to study the vibration behavior of cutting tool during turning operation under different experimental parameter conditions.

II. METHODOLOGY

The core part of the present study is the experimentation process under different parametric conditions Therefore, at first, the material selection is the starting task followed by the system component selection. The system components other than the conventional lathe machine setup are ADXL335 vibration sensor and the Arduino UNO software tool.After the system constituents the experimental setup is prepared and the experimentation process has been performed. For conducting the experimentation process under different configurations, the Design of Experiment (DOE) process has been employed for the identification of reliable system configurations. Two different techniques of DOE: Taguchi and Analysis of variance (ANOVA) are used. Based on the configurations derived by DOE, the experimentation was performed and the observations were recorded.Based on the observation the regression expressions of different orders are developed for the identification of system performance for diverse combination of input parameters without performing the experimentation.

III. EXPERIMENTAL SETUP

The experimental setup consists of a typical lathe machine augmented by means of ADXL335 vibration sensor and the Arduino UNO software tool for the investigation of vibrations for different apparatus configurations.

3.1 Material selection

EN8 is an unalloyed medium carbon steel utilized in purposeswhere preferable special characteristics are desired and the expenses don't legitimize the acquisition of composites[16]. EN8 can be surface hardened along with the reasonablewear obstruction properties by means of proper heat treatment. EN8 is utilized in auto parts, associating streets, studs, bolts, axles, axles, general designing segments and so forth.

Table 1. EN8 mechanical properties

Parameter	Value
Max Stress	700-850 N/mm2
Yield Stress	465 N/mm2 Min
0.2% Proof Stress	450 N/mm2 Min
Elongation	16% Min
Impact KCV	28 Joules Min
Hardness	201-255 Brinell

3.2 ADXL335vibration sensor

The ADXL335 is a little, dainty, low-power, total 3-pivot accelerometer with signal adapted voltage yields. Itassessesthe speed increase with a base full-scale scope of ±3 g. The accuracy of this sensor is ±0.05 g. It can quantify the static speed increase of gravity in slant detecting applications, just as powerful speed increase coming about because of movement, stun, or vibration[17].

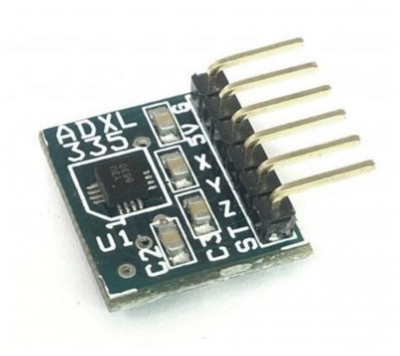


Fig.1. ADXL335 vibration sensor

3.3 Arduino UNO

Arduino is an open-source gadgets stage dependent on simple to-utilize equipment and programming. Arduino sheets can understand inputs - light on a sensor, a finger on a catch, or a Twitter message - and transform it into a yield - actuating an engine, turning on a LED, distributing something on the web [4]. You can guide your board by sending a bunch of directions to the microcontroller on the board. Arduino Uno is a microcontroller board dependent on the ATmega328P (datasheet) [7]. It has 14 advanced information/yield pins (of which 6 can be utilized as PWM yields), 6 simple data sources, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB association, a force jack, an ICSP header and a reset button. It contains all that expected to help the microcontroller; basically interface it to a PC with a USB link or force it with an AC-to-DC connector or battery to begin. Perusing is taken in the Arduino programming.

Fig.2. Arduino UNO

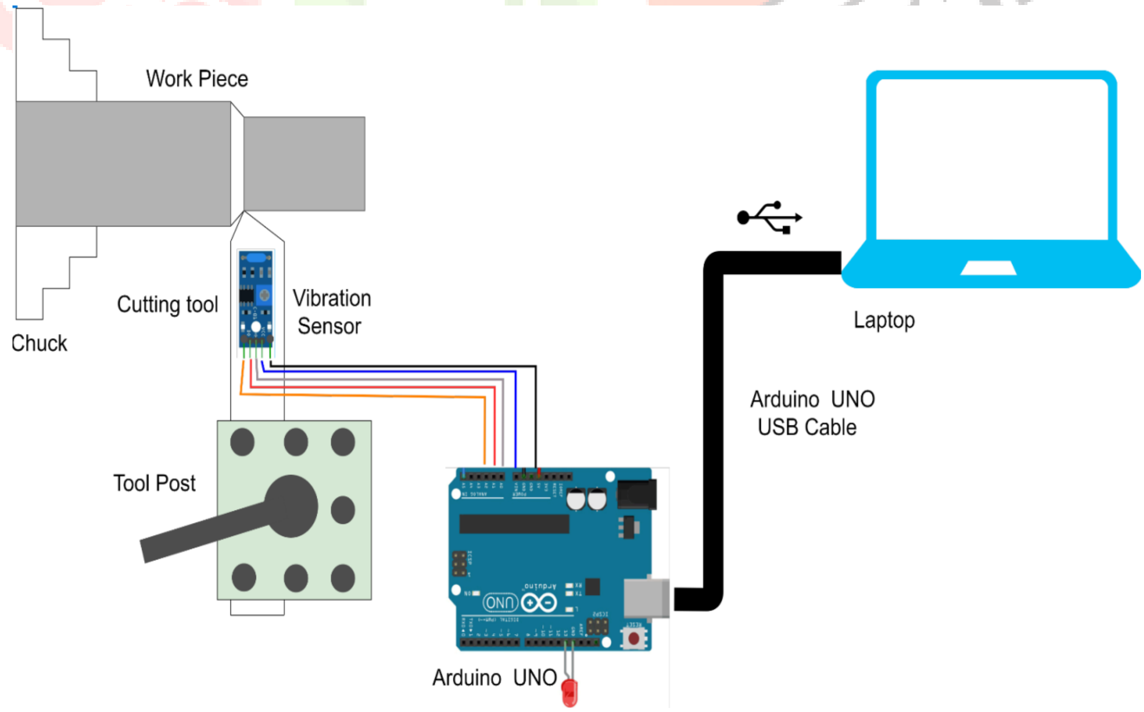


Fig.3. Schematic representation of the experimental setup with Arduino UNO

3.4 Experimentation

For the experiments, 270 mm long work-piece with different diameter (as per the parameter levels) are taken. In which 70 mm length is held in chuck and 200 mm is for experimentation. The carbide tool is used for the turning operation. To measure the vibration at low cost, Vibration sensor ADXL335 and Arduino UNO is taken. As per the DOE table, conduct the all experiments and vibration output directly stored in excel sheet.

The carbide-tipped devices hold their front line hardness at high machining temperatures produced by high cutting paces and feeds that decrease machining process duration [16]. Moreover, the carbide-tipped apparatuses improve surface completion and hold size far longer for better quality. The carbide tools do not require sharpening or steep learning curve and the carbide tips stay sharp longer than high-speed steel (HSS). Hence, the carbide tool was used for the experiments. For the experiments,the tool was hold 30 mm outside from the tool holder. The vibration sensor was places on the tool near to tip asthe vibrationsare highest at the tip. The speed range of 225-800 RPM was maintained throughout the experimentations.

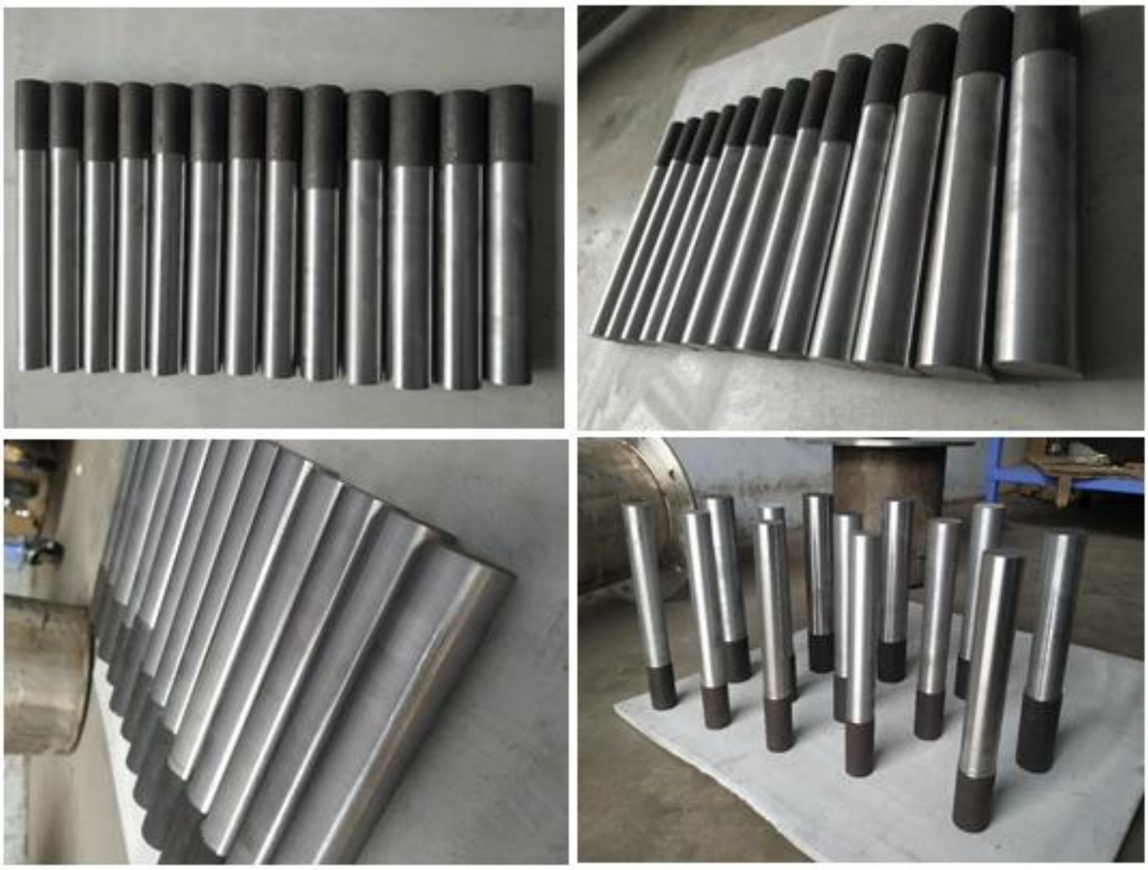


Fig.4. Experimental specimen of work-piece

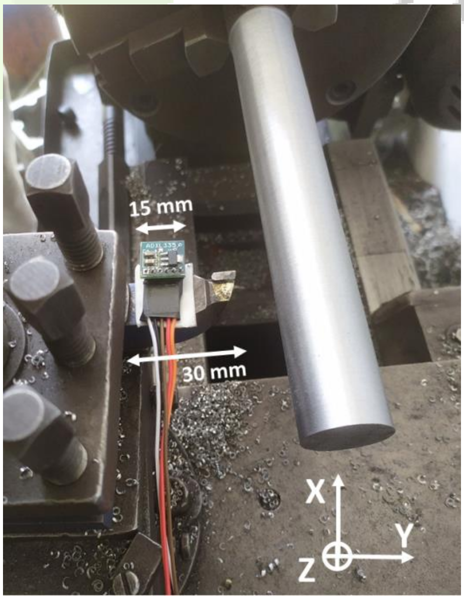


Fig.5. Experimental setup with dimensional depiction

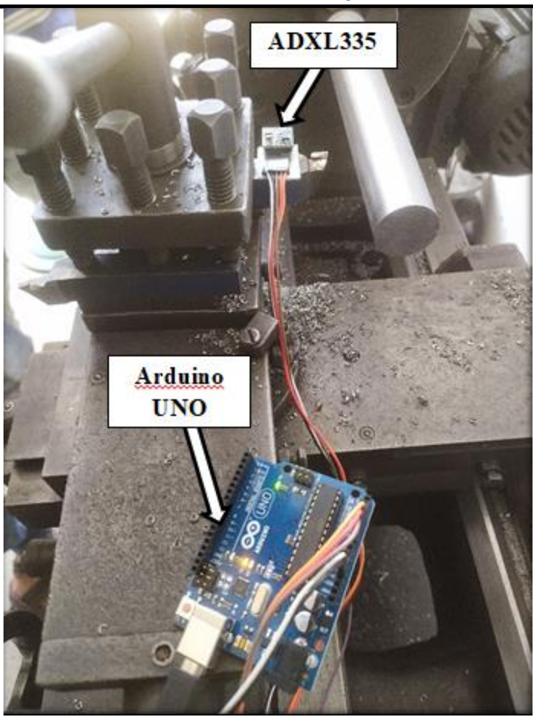


Fig.6. Experimental setup with Arduino UNO and ADXL335

IV. DESIGN OF EXPERIMENTS (DOE)

As elaborated in the methodology, DOE has been implemented for the derivation of the parameters configurations for the experimentation. The factors considered for the study are rotational speed of the spindle i.e. work-piece, feed rate, depth of cut (DOC) and the work-piece diameter. With the variation ranges of 225-800 RPM, 0.3-0.6 mm/rev, 0.5-1.25 mm and 20-50 mm in respective order. The factor levels of the parameter configurations are tabulated in Table 2. Further the DOE approach of Taguchi and ANOVA are applied for the further thorough investigation.

Table 2.Factors and levels for DOE

Factors	Levels			
	Level 1	**Level 2**	**Level 3**	**Level 4**
Rotational Speed (RPM)	225	350	500	800
Feed rate(mm/rev)	0.3	0.4	0.5	0.6
Depth of cut(mm)	0.5	0.75	1.0	1.25
Diameter (mm)	20	30	40	50

4.1 Taguchi approach of DOE

In view of our boundaries and levels, the conceivable cluster is the L16 symmetrical exhibit according to the Taguchi technique (allude to Table 3 with regards to the current examination). Dr. Taguchi used an extraordinary arrangement of symmetrical clusters (OAs) to design his examinations. Each line addresses a preliminary condition with a factor level showed by the number in the line. The upward section relates to the variables determined in the investigation.

Table 3. L16 table

Sr. no.	Speed (rpm)	Feed (mm/rev)	DOC (mm)	Diameter (mm)
1	225	0.12	0.1	30
2	225	0.13	0.3	35
3	225	0.14	0.5	40
4	225	0.15	0.7	45
5	350	0.12	0.3	40
6	350	0.13	0.1	45
7	350	0.14	0.7	30
8	350	0.15	0.5	35
9	500	0.12	0.5	45
10	500	0.13	0.7	40
11	500	0.14	0.1	35
12	500	0.15	0.3	30
13	800	0.12	0.7	35
14	800	0.13	0.5	30
15	800	0.14	0.3	45
16	800	0.15	0.1	40

4.2 ANOVA approach of DOE

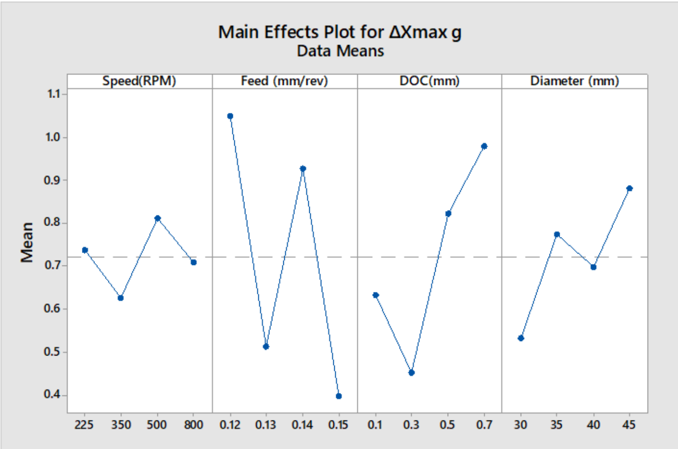
ANOVA is an assortment of measurable models and their related assessment methodology, (for example, the "variety" among and between gatherings) used to investigate the distinctions among implies. ANOVA can assist with knowing whether there are critical contrasts between the methods for your autonomous factors.Table 4 indicates the input parameters combinations and the corresponding outcomes. Based on the observations, the optimum parameter values identified are: N = 350 RPM, f = 0.15mm/rev, dC = 0.3 mm and D = 40 mm.The conforming main effect plot and the SN ratio depiction are given in Fig.7 and Fig.8 respectively. Moreover, the percentage impact of each input parameter is tabulated in

Table 5 and also depicted in Fig.9.

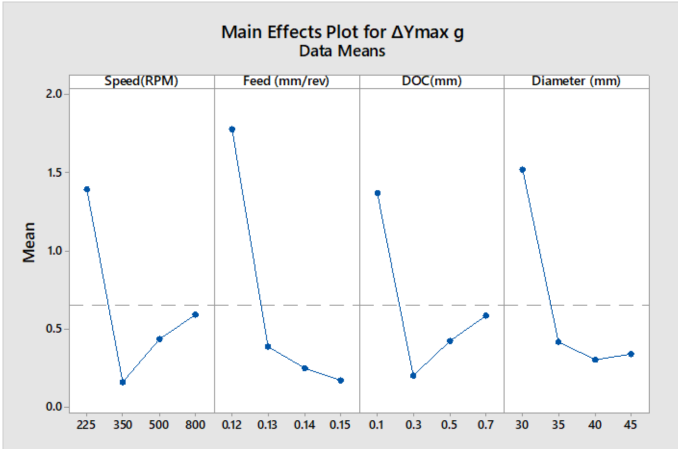
Table 4. DOE parameters for 0-200 mm size from the free end

Sr. no.	Speed (*N*)	Feed (*f*)	DOC (d_C)	Diameter (*D*)	$\Delta X_{max\ g}$	$\Delta Y_{max\ g}$	$\Delta Z_{max\ g}$
1	225	0.12	0.1	30	0.58	5.03	3.47
2	225	0.13	0.3	35	0.22	0.12	0.41
3	225	0.14	0.5	40	1.18	0.21	0.46
4	225	0.15	0.7	45	0.97	0.24	0.31
5	350	0.12	0.3	40	0.80	0.18	0.33
6	350	0.13	0.1	45	0.65	0.10	0.16
7	350	0.14	0.7	30	0.81	0.23	0.31
8	350	0.15	0.5	35	0.25	0.16	0.37
9	500	0.12	0.5	45	1.31	0.69	1.58
10	500	0.13	0.7	40	0.63	0.69	0.56

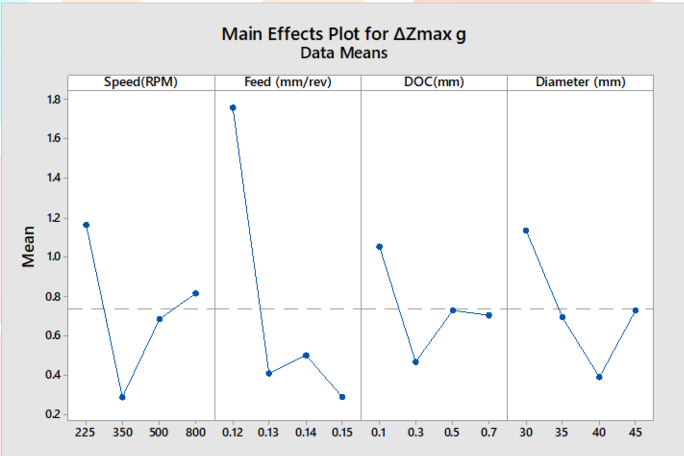
11	500	0.14	0.1	35	1.12	0.21	0.36
12	500	0.15	0.3	30	0.19	0.17	0.25
13	800	0.12	0.7	35	1.51	1.21	1.65
14	800	0.13	0.5	30	0.55	0.66	0.51
15	800	0.14	0.3	45	0.60	0.36	0.88
16	800	0.15	0.1	40	0.18	0.15	0.23



(a)



(b)



(c)

Fig.7. Main effect plot (0-200 mmsize from the free end) for (a) ΔX_{maxg}, (b) ΔY_{maxg} and (c) ΔZ_{maxg}

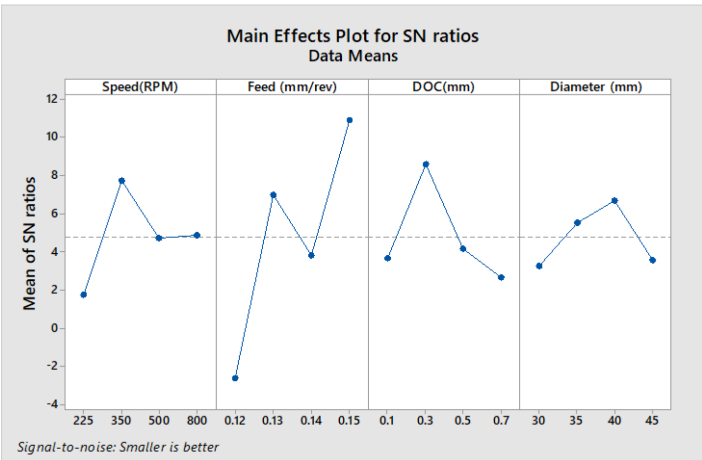


Fig.8. S-N ratio (0-200 mm size from the free end)

Table 5.Percentage contribution of parameter for tool vibration

Size in mm from free end	Direction	Speed (RPM)	Feed (mm/rev)	DOC (mm)	Diameter (mm)
0-50	ΔX	16.32	22.53	28.68	22.12
	ΔY	23.17	11.47	38.17	16.09
	ΔZ	12.41	54.06	6.38	11.93
50-100	ΔX	5.05	26.15	19.52	23.31
	ΔY	26.07	28.97	27.09	3.17
	ΔZ	14.46	43.75	7.37	16.10
100-150	ΔX	6.53	51.83	7.81	14.65
	ΔY	16.73	29.90	15.03	21.50
	ΔZ	25.18	29.08	14.95	14.27
150-200	ΔX	11.20	35.69	28.32	15.59
	ΔY	15.92	34.60	15.18	17.38
	ΔZ	12.77	41.26	14.53	14.95
0-200	ΔX	2.70	47.08	24.77	10.24
	ΔY	15.42	31.43	14.09	18.69
	ΔZ	14.17	51.32	6.38	10.12

Fig.9. Percentage contribution of parameter for tool vibration

V. REGRESSION ANALYSIS

In order to develop an empirical relation among the independent and dependent parameters the regression analysis has been performed using different polynomial orders as elaborated below.

Regression equations for assuming Polynomial relation of order 2 can be given as following:

$$\Delta Xg = 1.455 + 20.49 f + 18.75 f^2 - 98.12 d_c + 2.10 d_c^2 + 0.006 D \quad (1)$$

$$\Delta Y_g = 88.92 - 0.01N - 93.52 f + 3281.25 f^2 - 7.696 d_c + 8.297 d_c - 0.926 D + 0.014 D^2 \quad (2)$$

$$\Delta Z_g = 71.65 - 0.006N - 809.2 f + 2837.5 f^2 - 3.215 d_c + 3.531 d_c^2 - 0.611 D + 0.008 D^2 \quad (3)$$

Regression equations for assuming Polynomial relation of order 3 can be given as following.

$$\Delta Xg = 733.5 - 0.01N - 1724.6 f + 128.1 f^2 - 31635 f^3 - 7.304 d_c + 21.17 d_c^2 - 15.88 d_c^3 + 3.299 D - 0.008 D^2 \quad (4)$$

$$\Delta Y_g = 629.9 - 0.006N - 11625 f + 82762 f^2 - 196250 f^3 - 19.7 d_c + 44.48 d_c^2 - 30.16 d_c^3 - 5.496 D + 0.135 D^2 - 0.001 D^3 \quad (5)$$

$$\Delta Z_g = 751.7 - 0.0523N - 16650 f + 120625 f^2 - 233890 f^3 - 12.63 d_c + 31.91 d_c^2 - 23.65 d_c^3 + 2.194 D - 0.068 D^2 \quad (6)$$

Regression equations for assuming Polynomial relation of order 2 including cross-terms can be given as following.

$$\Delta Xg = 1.09 + 0.037N + 144.9 f - 173.6 f^2 + 8.193 d_c + 1.987 d_c^2 - 0.244 D + 0.002 D^2 - 0.089 Nf - 0.001 Nd_c - 58.50 fd_c + 0.196 fD + 0.038 d_c D \quad (7)$$

$$\Delta Y_g = 38.79 - 0.0423N - 287.4 f + 1176.2 f^2 - 57.54 d_c + 11.48 d_c^2 + 0.144 D + 0.003 D^2 + 0.138 Nf + 0.001 Nd_c + 207.7 fd_c - 5.101 fD + 0.421 d_c D \quad (8)$$

$$\Delta Z_g = 29.51 - 0.014N - 23.08 f + 1321.6 f^2 - 25.65 d_c + 6.021 d_c^2 - 0.172 D - 0.005 D^2 - 0.007 Nf + 0.003 Nd_c + 56.76 fd_c - 3.98 fD + 0.303 d_c D \quad (9)$$

R-squared is an integrity of-fit measure for direct relapse models. R-squared measures the strength of the connection between your model and the reliant variable on an advantageous 0-100% scale. The R-Square values for each of the three dependent variables for all three considered polynomial types are presented in Table 6; and the 2nd order polynomial with cross-terms has been identified to be the most reliable one with the highest R-Square values of 86.47, 91.79 and 91.43 for three dependent parameters.

Table 6.R-Square values for the considered three regression fits

Polynomial Order	Direction	R-Square (%)
2	X	46.71
	Y	70.95
	Z	66.12
3	X	84.86
	Y	79.65
	Z	82.02
2 (Cross Term)	X	86.47
	Y	91.79

	Z	91.43

VI. CONCLUSION

In the present study, the performance of the cutting tool subjected to vibration has been investigated which depends upon the operational parameters of the systems. As the experimentation is the most reliable means of investigating the vibrational behaviour of the cutting tool during the turning operation on work-piece; and the empirical expressions developed based on the well-designed experimental observations give much reliable predictions. The core contribution of the present study is the application of DOE approach with Taguchi and ANOVA techniques on the vibration study of cutting tool considering the four key variables: rotational speed (N) of the spindle i.e. work-piece, feed rate (f), depth of cut (DOC) (dC) and the work-piece diameter (D). Based on the observations, the optimum parameter values identified are: N = 350 RPM, f = 0.15mm/rev, dC = 0.3 mm and D = 40 mm. Moreover, the second order polynomial equation with cross-terms has been identified as the more suitable regression expression than the second and third order polynomial. The present study will benefit future researchers in defining the regression equations and using the same for different input conditions which will reduce the experimental cost requirements and will provide reliable predictions.

VII. ACKNOWLEDGMENT

It gives me immense pleasure to thank all those who have contributed to this study in innumerable ways. First and foremost I am deeply grateful to my research supervisor Dr. Jeeteendra A. Vadher, Mechanical Engineering Department, Government Engineering College, Palanpur for her guidance, support and motivation. Her sharp insight, perfect guidance and affectionate attitude have helped me overcome all research related problems. No amount of thanks would suffice the laborious hours she spent going through the different drafts of thesis at different stages and offering me the much needed guidance. I take this opportunity to convey my sincere thanks to my Doctoral Progress Review Committee members Dr. V. N. Patel and Dr. D. A. Desai, G H Patel College of Engineering & Technology, Vidhyanagar for their scholarly guidance and resourceful feedback throughout my research work. Their valuable suggestions have given a proper direction to my research.

VIII. REFERENCES

[1] PWE, Vibration - an age-old problem! - Plant & Works Engineering, 2014.

[2] S.A. TOBIAS, W. FISHWICK, Theory of regenerative machine tool chatter, 1958.

[3] N. Fang, P.S. Pai, S. Mosquea, Effect of tool edge wear on the cutting forces and vibrations in high-speed finish machining of Inconel 718: An experimental study and wavelet transform analysis, Int. J. Adv. Manuf. Technol. 52 (2011) 65–77. https://doi.org/10.1007/s00170-010-2703-6.

[4] N.V.S. Shankar, H.R. Shankar, N.P. Kumar, K. Saichandu, Process Parameter Optimization for Minimizing Vibrations and Surface Roughness During Turning EN19 Steel Using Coated Carbide Tool, Mater. Today Proc. 24 (2020) 788–797. https://doi.org/10.1016/j.matpr.2020.04.387.

[5] R.L. Hecker, G.M. Flores, Q. Xie, R. Haran, SERVOCONTROL OF MACHINE-TOOLS : A REVIEW, Letin Am. Appl. Res. 94 (2008) 85–94.

[6] M. Girish Kumar, P. Vinod, P. V Shashikumar, Investigation and Analysis of Chatter Vibration in Centerless Bar Turning Machine, 2014.

[7] N.V.S. Shankar, A.G. Chand, K.H. Rao, K.P. Sai, Low Cost Vibration Measurement and Optimization During Turning Process, Adv. Mater. Res. 1148 (2018) 103–108. https://doi.org/10.4028/www.scientific.net/AMR.1148.103.

[8] K.H. Hajikolaei, H. Moradi, G. Vossoughi, M.R. Movahhedy, Spindle speed variation and adaptive force regulation to suppress regenerative chatter in the turning process, J. Manuf. Process. 12 (2010) 106–115. https://doi.org/10.1016/j.jmapro.2010.08.002.

[9] E. Bagci, Monitoring and analysis of MRR-based feedrate optimization approach and effects of cutting conditions using acoustic sound pressure level in free-form surface milling, Sci. Res. Essays. 6 (2011) 256–277.

[10] A. Un, Intelligent adaptive control and monitoring of band sawing using a neural-fuzzy system, J. Mater. Process. Technol. 9 (2008) 2302–2313. https://doi.org/10.1016/j.jmatprotec.2008.05.031.

[11] A. Al-shayea, F.M. Abdullah, M.A. Noman, H. Kaid, E.A. Nasr, Studying and Optimizing the Effect of Process Parameters on Machining Vibration in Turning Process of AISI 1040 Steel, Adv. Mater. Sci. Eng. (2020).

[12] J. V Abellan, F. Romero, H.R. Siller, A. Estruch, C. Vila, Adaptive Control Optimization of Cutting Parameters for High Quality Machining Operations based on Neural Networks and Search Algorithms, in: Adv. Robot. Autom. Control, 2008: pp. 1–20.

[13] N. Hassan, Development of A Dynamic Model For Vibration During Turning Operation And Numerical Studies, 2014.

[14] P. Bansal, I.S.R. Vedaraj, Monitoring and Analysis of Vibration Signal in Machine Tool Structures, IJEDR. 2 (2014) 2310–2317.

[15] V. Sivaraman, L. Vijayaraghavan, S. Sankaran, Effect of Vibration on Surface Texture during Machining Multiphase Microalloyed Steel, Procedia Manuf. 10 (2017) 429–435. https://doi.org/10.1016/j.promfg.2017.07.019.

[16] N. Balabhadra, S. Ugender, Effects of Cutting Variables on MRR and Tool Wear for EN8 Medium Carbon Steel with carbide insert, 2015. www.ijiset.com (accessed May 7, 2021).

[17] I.B. Ã, L. Gallimard, S. Nikoukar, Optimal piezoelectric actuator and sensor location for active vibration control , using genetic algorithm, J. Sound Vib. 329 (2010) 1615–1635. https://doi.org/10.1016/j.jsv.2009.12.001.