NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 2, ISSUE 7, JULY-2015

PREDICTION AND CONTROL OF LATHE MACHINE TOOL VIBRATION BY USING PASSIVE DAMPING

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Abstract

In machining operation, the quality of surface finish is an important requirement for many turned work-pieces. Thus the choice of optimized cutting parameters is very important for controlling the required surface quality. The focus of present experimental study is to optimize the cutting parameters using two performance measures, machine tool vibration and work-piece surface roughness The prediction and control of vibration between the tool and work piece is important as guideline to the machine tools user for an optimal selection of depth of cut, cutting speed, tool feed rate to minimize the vibration. In machining operation there are different variables deleterious the desired result. In this process the behavior of machine tool, cutting tool life and cutting tool vibration are the complex phenomenon which influences on the dimensional precision of the components to be machined, the cutting tool vibrations are mainly influenced by cutting parameters like cutting speed, depth of cut and tool feed rate. In this project work, CNC lathe cutting tool vibrations are controlled the tool holder is supported with and without damping pad. To increase the accuracy of experiments, Taguchi L9 experimental design method has used in this experiment. Experimental result are validate with analysis of variance (ANOVA) and regression analysis to identify the influences of the different cutting parameter on the vibration of cutting tool.

Introduction

Machine and machine tool are always subjected to vibration. These vibrations are mainly causes due to In-homogeneity's in the work piece material Variation of chip cross section Disturbances in the work piece or tool drives Dynamic loads generated by acceleration/deceleration of massive moving components Vibration transmitted from the environment Self-excited vibration generated by the cutting process or by friction (machine-tool chatter). The tolerable level of relative vibration between tool and work piece, is determined by the required surface finish and machining accuracy as well as by detrimental effects of the vibration on tool life.

Machine tools operate in different configurations (positions of heavy parts, weights, dimensions, and positions of work pieces) and at different regimes (spindle rpm, number of cutting edges, cutting angles, etc.), different vibratory modes can be prominent depending on the circumstances. The stiffness of a structure is determined primarily by the stiffness of the most flexible component in the path of the force. To enhance the stiffness, this flexible component must be reinforced. To assess the influence of various structural components on the overall stiffness, a breakdown of deformation (or compliance) at the cutting edge must be constructed analytically or experimentally on the machine. Breakdown of deformation (compliance) in tensional systems (transmissions) can be critically influenced by transmission ratios between the components.

Vibration Due to in homogeneities in the Work piece

Hard spots or a crust in the material being machined impart small shocks to the tool and work piece, as a result of which free vibrations are set up. When machining is done under conditions resulting in discontinuous chip removals, the segmentation of chip elements results in a fluctuation of the cutting thrust. If the frequency of these fluctuations coincides with one of the natural frequencies of the structure, forced vibration of appreciable amplitude may be excited. However, in single edge cutting operations, it is not clear whether the segmentation of the chip is a primary effect or whether it is produced by other vibration, without which continuous chip flow would be encountered. The breaking away of a built-up edge from the tool face also imparts impulses to the cutting tool which result in vibration. However, marks left by the built-up edge on the machined surface are far more pronounced than those caused by the ensuing vibration; it is probably for this reason that the built-up edge has not been studied from the vibration point of view. The built-up edge frequently accompanies certain types of vibration, and instances have been known when it disappeared as soon as the vibration was eliminated [4].

Vibration Due To Cross-Sectional Variation of Removed Material

Variation in the cross-sectional area of the removed material may be due to the shape of the machined surface or to the configuration of the tool. In both cases, pulses of appreciable magnitude may be imparted to the tool and to the work piece, which may lead to undesirable vibration. The pulses have relatively shallow fronts for turning of no round or eccentric parts, and steep fronts for turning of slotted parts and for milling broaching. These pulses excite transient vibrations of the frame and of the drive whose intensity depends on the pulse shape and the ratio between the pulse duration and the natural periods of the frame and the drive. If the vibrations are decaying before the next pulse occurs, they can still have a detrimental effect on tool life and leave marks on the machined surface. They may be eliminated or minimized by closing the recess with a plug or with filler. When the transients do not significantly decay between the pulses, dangerous resonance vibrations of the frame and/or the drive can develop with the fundamental and higher harmonics of the pulse sequence. The danger of the resonance increases with higher cutting speeds. Simultaneous engagement of several cutting edges with the workpiece results in an increasing dc component of the cutting force and effective reduction of the pulse intensity, while run out of a multiage cutter and inaccurate setup of the cutting edges enrich the spectral content of the cutting force and enhance the danger of resonance. Computational synthesis of the resulting cutting force is reasonably accurate [2].

Vibration Control in Machine Tools

The vibration behaviour of a machine tool can be improved by a reduction of the intensity of the sources of vibration, by enhancement of the effective static stiffness and damping for the modes of vibration which result in relative displacements between tool and work piece, and by appropriate choice of cutting regimes, tool design, and work piece design. Abatement of the sources is important mainly for forced vibrations. Stiffness and damping are important for both forced and self-excited (chatter) vibrations. Both parameters, especially stiffness, are critical for accuracy of machine tools, stiffness by reducing structural deformations from the cutting forces, and damping by accelerating the decay of transient vibrations. In addition, the application of vibration dampers and absorbers is an effective technique for the solution of machine-vibration problems. Such devices should be considered as a functional part of a machine, not as an add-on to solve specific problems [3].

Increasing the flange thickness does not necessarily increase the stiffness of the connection, since this requires longer bolts, which are more flexible. There is an optimum flange thickness (bolt length), the value of which depends on the elastic deformation in the vicinity of the connection. Deformation of the bed is minimized by placing ribs under connecting bolts. The efficiency of bolted connections, and other static and dynamic structural problems, is conveniently investigated by scaled model analysis. Predict and suppressing the vibration level of cutting tool in CNC lathe, by using passive damping pad of viscoelastic material.

Literature Survey

Al-Habaibeh and Gindy [1] they have found in a machining operation, vibration is frequent problem, which affects the machining performance and in particular, the surface finish and tool life. Severe vibration occurs in the machining environment due to a dynamic motion between the cutting tool and the work piece. In all the cutting operations like turning, boring and milling, vibrations are induced due to the deformation of the work piece, machine structure and cutting tool .Also new systematic approach, ASPS, to optimize condition monitoring systems is described. The system utilizes O as method to minimize the experimental work needed and to give a good evaluation of the designed monitoring system. The average dependencies of the proposed systems are compared with the pattern recognition capability of a back propagation neural networks and a fuzzy logic classifier.

Ahmed SyedAdnan and SathyanSubbiah [2] have observed reduction in cutting forces and feed forces when transverse vibrations are applied. Chip thickness is also reduced and surface finish is improved upon application of vibration. This study investigates vibrations that are applied along the cutting edge and perpendicular to the cutting velocity. Such a vibratory motion is expected to provide a small sawing action that will enhance the ductile fracture occurring ahead of the cutting tool as the chip separates from the bulk work material. This enhancement in fracture will then contribute to reducing the chip thickness and cutting forces.

Y. Altintas and M.R. Khoshdarregiet [3] integrated vibration avoidance and contouring error compensation were experimentally demonstrated to improve the damping and contouring accuracy on a two-axis table. Also machine tools exhibit residual vibrations and give contouring errors during high speed, high acceleration contour machining operations. The vibrations are caused by the structural modes of the machine tool. The source of the contouring errors is both due to limited bandwidth of the servo drives as well as the vibration avoidance methods used in generating the trajectory commands.

S. S. Abuthakeeret al. [4] have worked on the cutting tool vibrations and control of cutting tool vibration using a damping pad made up of neoprene. Experiments were conducted in CNC lathe, were the tool holder is supported with and without damping pad. The cutting tool vibration signals were collected through a data acquisition system supported by Lab VIEW software. To increase the buoyancy and reliability of the experiment a full factorial experimental design was used. The experimental studies and data analysis have been performed to validate the proposed validate 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.

Chen et al. [5] have present on reliability estimation for cutting tools based on logistic regression model using vibration signals. The three steps of new reliability estimation approach for cutting tools are as follows. First, on-line vibration signals of cutting tools are measured during the manufacturing process. Second, wavelet packet (WP) transform is employed to decompose the original signals and correlation analysis is employed to find out the feature frequency bands which indicate tool wear. Third, correlation analysis is also used to select the salient feature parameters which are composed of feature band energy, energy entropy and time-domain features. Finally, reliability estimation is carried out based on logistic regression model. The approach has been validated on a NC lathe. Under different failure threshold, the reliability and failure time of the cutting tools are all estimated accurately.

Armando et al. [6] have studied the vibration analysis of cutting force in titanium alloy milling. The purpose of this work is to study the influence of the tool entering angle on the stability of the process and on tool life based on a time and frequency domain analysis of the cutting forces. Cutting forces are larger at lower entering angles, the tool life is much longer, since most of this load is associated with low frequencies, at which the tool behaves like a rigid body.

Wang et al. [7] have present on a theoretical and experimental investigation of the tool-tip vibration and its influence upon surface generation in single-point diamond turning (SPDT). In the present study, two characteristic peaks (twin peaks) are identified and found to be corresponding to the tool-tip vibrations by power spectrum density (PSD) analyses. The vibrations possess the features of small amplitude but high frequency. A physical model is proposed to capture the dominant factor based on the characteristic and it reveals that the twin peaks are attributed by the impact between the tool tip and workpiece and the process damping effect. Hence, a geometric model of surface roughness is proposed to take account of tool-tip vibration and it is verified through a series of experiments.

Marcus et al. [8] have studied the vibration reduction using passive absorption system with Coulomb damping. This research aims at investigating the possibility of using the Coulomb damping, mainly to lessen they vibrations of structures submitted to human loadings. The great advantage in using this type of damping is that we can easily obtain high levels of damping with values well controlled and adjusted to the need of the project. A computational–theoretical model was developed to represent a structural system with Coulomb damping, containing two degrees of freedom. In order to calibrate this model some experimental tests were carried out with a cantilever beam. A parametric study was performed after the theoretical–computational model had been adjusted. The results indicate that the system is only applicable to some situations, and care should be taken in the design.

Objectives of the Project

It is observed that most of researcher have focused on effect causes parameter on vibration and effect of vibration on various parameter like surface roughness, life of cutting tool, reliability of system etc .Also they provide suitable solution for that. But they very little focused on damping treatments in actual applications which based on viscoelastic materials with viscous devices being the second most actively used (the use of viscous devices is greater for isolation and shock) and method of control of the machine tool vibration. Predict and suppressing the vibration level of cutting tool in CNC lathe, by using passive damping pad of viscoelastic material.

Experimental Methodology and Experimentation

It is methodology based on statistics and other discipline for arriving at an efficient and effective planning of experiments with a view to obtain valid conclusion from the analysis of experimental data. Design of experiments determines the pattern of observations to be made with a minimum of experimental efforts. To be specific Design of experiments (DOE) offers a systematic approach to study the effects of multiple variables / factors on products / process performance by providing a structural set of analysis in a design matrix. Number of Experiments to be performed is decided with the help of Taguchi Method It is assume that inherent vibration, tool wear and L/D are constant throughout experimentation and Cutting Speed, Depth of cut, nose radius & feed rate are varied at different levels. All varying parameter are varied at 3 levels as follows:

Table1. Level of Experimental Parameters

Parameters	**Level 1**	**Level 2**	**Level 3**
Nose Radius (NR)	0.4	0.8	1.2
Cutting speed (CS) C1	420	520	620
Depth of cut (DOC) C2	0.4	0.5	0.6
Feed rate(FR) C3	0.15	0.20	0.25

According to above input to the Minitab-15 software for optimum no of experiments it gives the L9 orthogonal array for various combinations of the different levels of the three factors.

Experimental Details

The experimental setup for this project is as shown in figure. It includes a CNC lathe of turning with MIDAS-0 turning centre tool holder, work piece without any cutting fluid. The tool is instrumented with two accelerometer (of Brule& Kjaer type 4517).The accelerometer signals has taken to data aquistation card system using lab view software. The vibration data is captured by DAC system. This include hardware section, circuit design & implementation hardware interface, circuit turbo shooting, filtering, computer software programming. For experiment purpose work piece of SS304 is used. Shape of work piece is solid round bar. Dimension of solid round bar is of Diameter of 30 mm and length is 30mm.

Figure 1: Experiment Set up

For experiment purpose insert triangular shape is use. It is manufactured by SANDVIK Company. Specification of insert is TNMG 160408-61 having grade no. 4015.

Table2. Observation for Silicon Damper

Sr No	NR	CS	DC	FR	Amplitude of Acceleration of cutting tool in g				Surface Roughness	
					Axial Direction (RMS)		Tangential Direction (RMS)			
					Without Damper	With Damper	Without Damper	With Damper	Without Damper	With Damper
1	0.4	420	0.4	0.15	1.833	1.46	2.65	1.93	1.684	1.086
2	0.4	520	0.5	0.2	2.8	2.1	4.7	2.93	1.67	1.014
3	0.4	620	0.6	0.25	3.89	3.28	7.6	5.99	2.461	1.475
4	0.8	420	0.5	0.25	2.59	1.66	6.31	3.29	2.26	1.223
5	0.8	520	0.6	0.15	4.38	2.29	10.13	4.36	1.805	1.654
6	0.8	520	0.4	0.2	10.29	2.55	7.36	5.36	2.401	1.776
7	1.2	420	0.6	0.2	2.02	1.97	4.32	2.69	2.08	1.682
8	1.2	520	0.4	0.25	3.02	2.88	8.01	3.43	2.204	0.587
9	1.2	620	0.5	0.15	4.3	4.05	12.51	4.46	2.60	1.044

Result and Discussion

The vibration phenomenon for various cutting condition has been analyzed using Lab VIEW software. The plan of the experiment was developed not only to assess the effect of cutting speed, feed rate and depth of the cut but also to study the effect of damping pad on the cutting tool vibration, tool temperature and surface roughness. Table illustrates the experimental result of vibration in both tangential and axial cutting direction. After analysis of the vibration, passive damping pad is provided below the cutting tool elements. Now the same experiment was carried out for various cutting condition and at various damping material, also corresponding cutting tool vibration and surface roughness are measured.

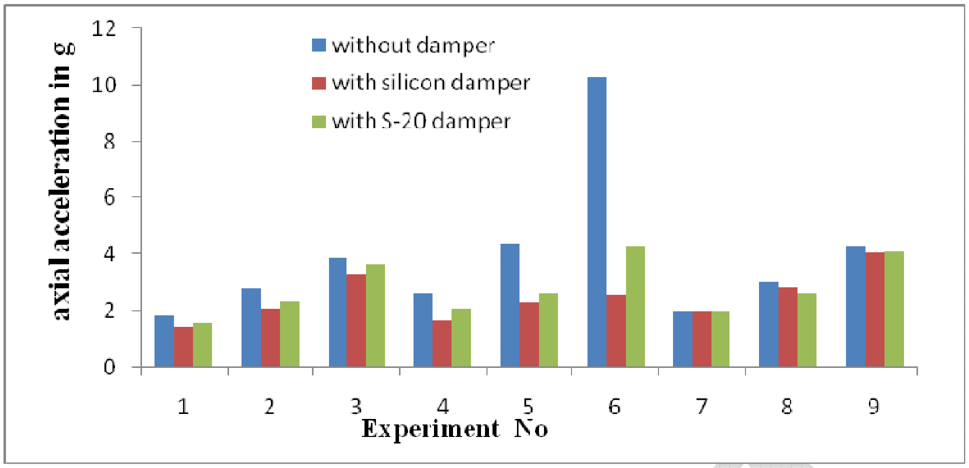

Fig 2.Comparison of damper based on axial acceleration

It is observed that after using passive damping, axial acceleration of machine tool is getting reduced. Out of these dampers Silicon damper having maximum damping capacity than S-20 damper Silicon damper absorbed 26.8% axial acceleration while S-20 dampers absorb only 14.9%, Silicon damper absorbed 41.75% Tangential Acceleration while S-20 dampers absorb only 15.91%.

Regression Analysis:-

By using this data we can compare the vibration parameter with damp condition and without damp condition. Also ANOVA and Regression analysis can validate above result.

The Regression for Axial Acceleration without Damper

Axial Acceleration =0.858333N R + 0.007978SS +1.105556DoC +0.033333 FR -2.91937

Regression Statistics

Table3. Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	5.26410	1.31603	33.24	0.003
NR	1	0.70727	0.70727	17.86	0.013
CS	1	4.48635	4.48635	c113.30	0.000
DC	1	0.01697	0.01697	0.43	0.548
FR	1	0.00007	0.00007	0.00	0.969
Error	4	0.15838	0.03960		
Total	8	5.42249			

Table No. 4 From above discussion we observed that R Square is 86 % while adjusted R Square is 80 %. Therefore it indicated that cutting parameters closely co-related with axial acceleration.

Regression Statistics	
Multiple R R Square Adjusted R Square Standard Error Observations	0.867294 0.8078 0. 707144 0.454549 9

Regression for Tangential Acceleration with Silicon damper

Tangential Acceleration =3.38 N R + 0.0241 SS +0.105 DoC -0.967 FR -9.51

SUMMARY OUTPUT

TABLE 5.From above discussion we observed that R Square is 96 % while adjusted R Square is 92 %. There for it indicated that cutting parameters closely co-related with axial acceleration.

Regression Statistics	
Multiple R	0.960523742
R Square	0.922605859
Adjusted R Square	0.908534197
Standard Error	0.725483178
Observations	09

CONCLUSION

1) A multiple regression model has been developed and validated with experimental results
2) Passive damping can provide substantial performance benefits in many kinds of structures and machines, often without significant weight or cost penalties. In all aspects of the studies performed, a significant reduction in tool vibration during machining was achieved for a CNC machining operations.
3) From ANOVA it is clear that feed rate is most influencing parameter for both axial acceleration and surface roughness.

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