

Prediction and control of Lathe Machine tool vibration – A Review

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ABSTRACT

The present work concentrates and aims on study of different controllable parameter that affects the responses like vibration amplitude. The prediction 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 and rotation of spindle to minimize the vibration. Machining is a complex process in which different parameters can deleterious the desired result. Among them, cutting tool vibration is an important which influences dimensional precision of components machined, life of the cutting tool is very important. Cutting tool vibration are mainly produced cutting parameters like cutting speed, depth of cut and tool feed rate. In this work, the cutting vibrations are controlled in lathe machine where the tool holder is supported with and without damping pad. The cutting tool vibration signals were controlled through FFT analyzer. To predict and validate result by using Taguchi method, Experimental studies and data analysis have been performed to validate the proposed damping system. By using regression analysis best suitable equation is developed to predict the probable value response for given predictor value.

Keyword: - Cutting Tool Vibration, FFT Analyzer, Taguchi Method, ANOVA etc.

1. Introduction

Metal cutting or simply machining, is one of the oldest processes for shaping components in the manufacturing industry. To remain in business, manufacturing companies have to machine the components at required quality with minimum possible cost and hence the tool life becomes a most important aspect for manufacturing engineers and researcher. The challenge of modern machining industries is focused mainly on the achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact. Tool wear weakens the cutting tool, increases the forces used in cutting and causes a lack of consistency in material removal. 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.

1.1 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].

1.2 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].

1.3 Disturbances in the Work piece and Tool Drives

Forced vibrations result from rotating unbalanced masses; gear, belt, and chain drives; bearing irregularities; unbalanced electromagnetic forces in electric motors; pressure oscillations in hydraulic drives; etc. vibration caused by rotating unbalanced Members. Forced vibration induced by rotation of some unbalanced member may affect both surface finish and tool life, especially when its rotational speed falls near one of the natural frequencies of the machine-tool structure. Lathes may be sensitive to work piece unbalance due to asymmetrical geometry or the no uniform allowance (e.g., forged parts). Marks Caused by Inhomogeneity's in the Grinding Wheel. Although grinding marks usually indicate the presence of a vibration, this vibration may not necessarily be the primary cause of the marks. Hard spots on the cutting surface of the wheel result in similar, though generally less pronounced marks. Grinding wheels usually are not of equal hardness throughout.

A hard region on the wheel circumference rap-idly becomes glazed in use and establishes itself as a high spot on the wheel (since it retains the grains for a longer period than the softer parts). These high spots eventually break down or shift to other parts of the wheel Marks which appear to be due to an unbalanced member rotating at two or three times the speed of the wheel and which are non-uniformly spaced are always due to two or three hard spots. Grinding marks resulting from unbalance of grinding wheel or some other component like cylindrical grinding, peripheral grinding. Marks which are unequally spaced or which have a varying slope are due to in-homogeneities in the wheel. The Effect of Vibration on the wheel properties may takes place. If vibration exists between wheel and work piece, normal forces are produced which react on the wheel and tend to alter the wheel shape and/or the wheel's cutting properties. In soft wheels the dominating influence of vibration appears to be inhomogeneous wheel wear, and in hard wheels inhomogeneous loading (i.e. Packingof metal chips on and in crevasses between the grits). These effects result in an increased fluctuation of the normal force, which produces further changes in the wheel properties. The overall effect is that a vibration once initiated tends to grow. When successive cuts or passes overlap, the inhomogeneous wear and loading of the wheel may cause a regenerative chatter effect which makes the cutting process dynamically unstable [1].

1.4 Vibration Control in Machine Tools

The vibration behavior 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].

1.5 Stiffness

Static stiffness k_s is defined as the ratio of the static force P_o , applied between tool and work piece, to the resulting static deflection A_s between the points of force application. A force applied in one coordinate direction is causing displacements in three coordinate directions; thus the stiffness of a machine tool can be characterized by stiffness matrix (three proper stiffness's defined as ratios of forces along the coordinate axes to displacements in the same directions, and three reciprocal stiffness's between each pair of the coordinate axes). Frequently only one or two stiffness's are measured to characterize the machine tool. Machine tools are characterized by high precision, even at heavy-duty regimes (high magnitudes of cutting forces). This requires very high structural stiffness. While the frame parts are designed for high stiffness, the main contribution to deformations in the work zone (between tool and work piece) comes from contact deformations in movable and stationary joints between components (contact stiffness). Damping is determined mainly by joints (log decrement $\Delta \equiv 0.15$), especially for steel welded frames (structural damping $\Delta \equiv 0.001$). Cast iron parts contribute more to the overall damping ($\Delta \equiv 0.004$), while material damping in polymer-concrete ($\Delta \equiv 0.02$) and granite ($\Delta \equiv 0.015$) is much higher. While the structure has many degrees of freedom, dangerous forced and self-excited vibrations occur at a few natural modes which are characterized by high intensity of relative vibrations in the work zone. Since 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.

1.6 Vibration Damping Material

Vibration damping material is used to reduce or eliminate noise in industrial, electronic, structural and ergonomic applications caused by resonance and vibration. Sorbothane is a great solution for most any application and our visco elastic polymer has been used in everything from small gadgets, protective footwear, the U.S. Air force Memorial, the Space Shuttle and beyond.

Example- Neoprene rubber, S-20 rubber, Silicon rubber, Natural rubber etc.

i) Damping:-Damping is the energy dissipation properties of a material or system under cyclical stress. It is the conversion of mechanical energy into thermal energy. The amount of energy dissipated is a measure of the material's damping level.

ii) Working of Vibration Damping:-Damping materials work by changing the natural vibration frequency of the vibrating surface and thereby lowering radiated noise and increasing the transmission loss of the material. Many applications and products are subject to vibration from internal, as well as external sources. The effect of this vibration can range in severity from a computer owner's perception of the quality of their noisy hard drive to the actual failure of a mechanical system due to a high-cycle fatigue.

iii) The most Common Damping Mechanism:-The most common damping mechanism used to address vibration (and noise) a problem is visco elastic damping. Visco elastic means that the material exhibits both elastic and viscous behavior. An elastic material is one that stores energy during a load and all energy is returned when that load is removed. A viscous material doesn't return any energy. All energy is lost as "pure damping" once the load is removed. A visco elastic material therefore stores some of the energy during a load and then the remainder is released as heat.

iv) The Difference between Vibration Isolation and Vibration Damping:-We have discussed vibration isolation before but it might be a good idea to define the difference here between vibration isolation and vibration damping. A good vibration isolation system will lower the natural frequency of a mechanical system below the excitation frequency. This keeps the natural and excitation frequency "out of sync" which in turn reduces the amount of vibration and potential problems.

v) A vibration damper takes energy out of the system. When you increase the damping in a mechanism or structure there will be a reduction in vibration and noise and the dynamic stresses applied will be reduced with a resulting benefit to the fatigue life – among many other benefits. Sorbothane can absorb over 50% of the vibration energy over most of its temperature operating range at frequencies from 10 to 30,000 Hertz.

vi) What are the Main Considerations When Choosing a Vibration Damper?

a) A good damping coefficient: - A damping coefficient is a material property that indicates whether a material will "bounce back" or return energy to a system. A basketball has a low damping coefficient (a good bounce back). If the bounce is caused by an unwanted vibration or shock, a high damping coefficient will

attenuate the response ("Swallow the energy" and reduce the reaction of the system.) Sorbothane has a superior damping coefficient, over a very wide temperature range, compared to any other polymer.

b) Wide temperature range stability: - The temperature range stability for materials must be known for use in the extreme application environments.

2. 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, where 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 extent. 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.

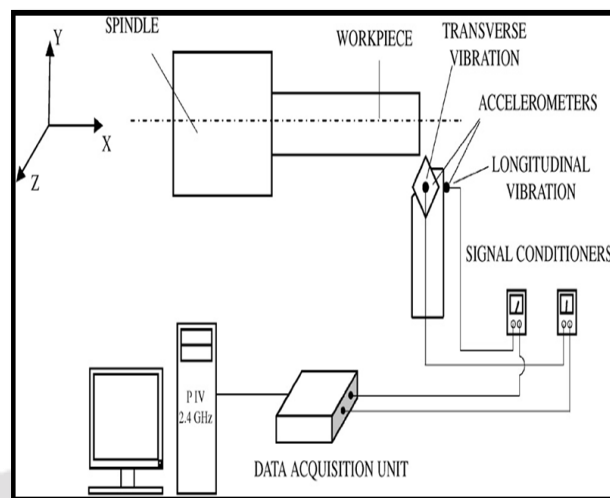
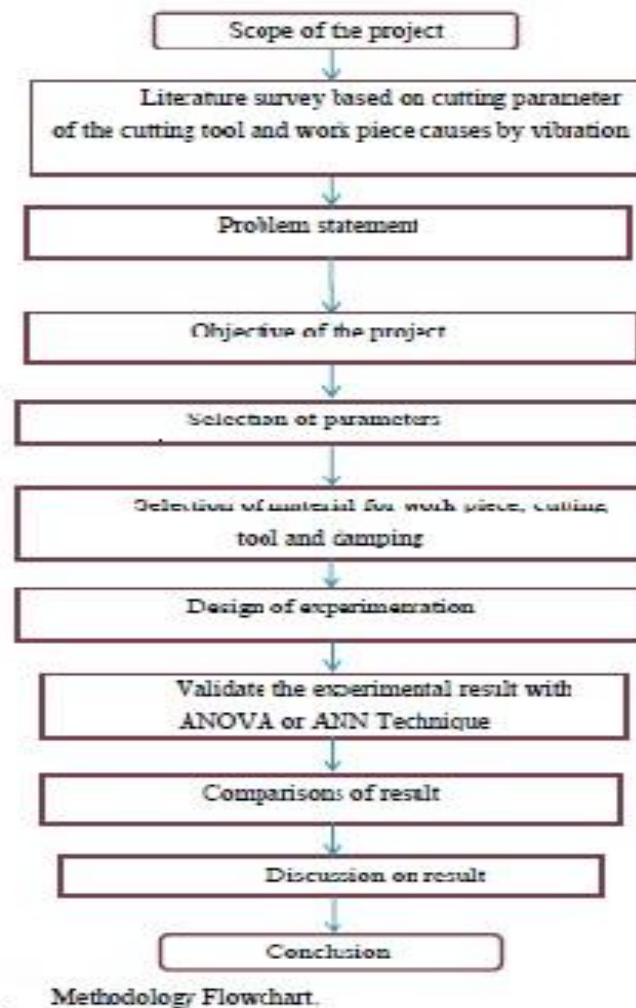
Marcus et al. [8] have studied the vibration reduction using passive absorption system with Coulomb damping. This research aims at investigating the possibility of using the Coulomb damping, mainly to lessen the vibrations of structures submitted to human loadings. The great advantage in using this type 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.

Alonsa and Salgado [9] have present on analysis of the structure of vibration signals for tool wear detection. The objective of this work is to develop a reliable tool condition monitoring system (TCMS) for industrial application. The proposed TCMS is based on the analysis of the structure of the tool vibration signals using singular spectrum analysis (SSA) and cluster analysis. SSA is a novel non-parametric technique of time series analysis that decomposes the acquired tool vibration signals into an additive set of time series. The results show that this use of SSA and cluster analysis provides an efficient automatic signal processing method, and that the proposed TCMS based on this procedure, is fast and reliable for tool wear monitoring.

Dimbla and Lister [10] have studied the on-line metal cutting tool condition monitoring. I: force and vibration analyses. This method for detecting and monitoring the wear on a cutting tool is therefore crucial in most metal cutting processes and several research efforts have striven to develop on-line tool condition monitoring systems. This paper describes an experimental and analytical method for one such technique involving the use of three mutually perpendicular components of the cutting forces (static and dynamic) and vibration signature measurements. The ensuing analyses in time and frequency domains showed some components of the measured signals to correlate well to the accrued tool wear.

3. METHODOLOGY:

However, in actual practice Lathe machine tool vibration occurs due 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/decelerate on of massive moving components, etc. In a machining operation, the cutting tool vibrations are mainly influenced by cutting parameters like cutting speed, depth of cut and tool feed rate. In this project the following methodology will be used.

Layout diagram of Experiment:**Fig -1:** Layout diagram of Experiment**Methodology:****Fig -2:** Methodology Flowchart.

4. PROBABLE OUTCOMES

By using damping material to predict and control lathe machine tool vibration. The cutting tool vibrations are mainly influenced by cutting parameters like cutting speed, depth of cut and tool feed rate. In this work, the cutting tool vibrations are controlled using various damping material. Experiments will be conducted in a lathe where the tool holder is supported with and without damping pad.

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