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Study of Cutting Tool Conditions on Machine Tool Vibration – A Literature Survey

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***Abstract*--Machining vibrations, also called chatter, correspond to the relative movement between the workpiece and the cutting tool. The vibrations result in waves on the machined surface. This affects machining processes, resulting in noise, bad surface quality and sometimes tool breakage. A survey has been made and many researchers have attempted the study of cutting tool conditions on tool vibration and also to construct several mathematical models based on various techniques. This paper presents literature review of articles for the past many years in order to explore how various techniques and prediction methodologies have been developed during this period in order to take care of tool vibrations in machines.**

Key Words: Machine vibration, chatter, cutting tool, machining process.

1. Introduction

Vibrations in the machine-tool system are a well-known fact in causing a number of machining problems, including tool wear, tool breakage, machine spindle bearings wear and failure, poor surface finish, inferior product quality and higher energy consumption. Vibrations can be classified in a number of ways according to a number of possible factors.

For instance, vibrations can be classified as free vibrations, forced vibrations and self-excited vibrations based on external energy sources. It is useful to identify vibrations types in machine tools. The machine tool chatter vibrations occur due to a self-excitation mechanism in the generation of chip thickness during machining operations. In turning or milling one of the structural modes of machine tool-work piece system is excited by cutting forces initially. An oscillatory surface finish left by one of the tooth is removed by the succeeding oscillatory tooth due to structural vibrations. The resulting chip thickness becomes also oscillatory, which in turn produces oscillatory cutting forces whose magnitudes are proportional to the time varying chip load. The self-excited cutting system becomes unstable, and chatter vibrations grow until the tool jump out of the cut or breaks under the excessive cutting forces. Thus the chatter vibrations continue which reduces the material removal rate. Chatter cannot be easily detected. Various methods are available for its detection and avoidance. Some of the details and reviews presented by various authors are presented below.

The paper is organized as follows: a review of literature survey on various techniques for tool vibration analysis and prediction is presented in section 2, followed by Section 3, with conclusion.

2. Literature Review

B. P. Kolhe, et. al.,(2015) analysed the CNC lathe cutting tool vibrations supported with and without damping pad. To increase the accuracy of experiments, Taguchi L9 experimental design method was used in this experiment. Experimental results were validated with analysis of variance (ANOVA) and regression analysis to identify the influences of the different cutting parameter on the vibration of cutting tool. A multiple regression model was developed and validated with experimental results. It showed that passive damping can provide substantial performance benefits in many kinds of structures and machines, often without significant weight or cost penalties.

N.Kusuma, Megha Agrawal, P.V.Shashikumar, (2014), worked on the influences of cutting parameters on machine tool vibration & surface finish using MEMS Accelerometer in high precision CNC milling machine. Investigation on the influences of cutting parameters on machine tool vibration & surface finish in high precision CNC milling machine shows that spindle speed has more significant effect on vibration and depth of cut has more significant effect on surface roughness in milling machine.

Amit Aherwar, Deepak Unune, BhargavPathri, Jai kishan, (2014), showed from experimental results, the amplitude of vibration of the cutting tool was ascertaining for each machining performance criteria. The significance and percentage contribution of each parameter were determined by Analysis of variance (ANOVA).It has been observed that cutting speed has a maximum contribution on cutting tool vibration in both the directions. Variation of the vibration of cutting tool with machining parameters was mathematically modelled by using the regression analysis method. The predicted value from the developed model and experimental values are found to be very close to each other justifying the significance of the model. Confirmation runs demonstrates that the optimized result and the values obtained through regression analysis are within the prescribed limit

K. Venkata Rao, B.S.N. Murthy, N. Mohan Rao, (2014), studied the vibration of work piece in boring of AISI 316 steel with cemented carbide tool inserts. A design of experiments was prepared with eighteen experiments with two levels of tool nose radius and three levels of feed rate and cutting speed. Experiments were performed on CNC lathe to obtain data amplitude of work piece vibration velocity. A new attempt is made with Laser Doppler Vibrometer (LDV) for online data acquisition of work piece vibration and a highspeed Fast Fourier transform analyzer was used to process the Acousto Optic Emission signals obtained from LDV. A multilayer feed forward artificial neural network (ANN) model was trained with the experimental data using backpropagation algorithm. Further, the ANN was used to predict amplitude of work piece vibration. The predicted values were compared with the collected experimental data and percentage error was computed. Less percentage of error was found between the experimental and predicted values.

In this work, eighteen experiments were conducted according to orthogonal array of L18. In each trial of experiment, a strong correlation among the dependent and independent variables was found. A neural network (4-14-8-1) was constructed with two hidden layers and trained with the experimental data. The network was trained with feed forward back propagation algorithm using 80 samples and validated for 20 samples. It was found that there is agreement between experimental data and neural network predicted values for amplitude work piece vibration (3.4816%. % of error). The neural network can help in selection of proper cutting parameters to reduce tool vibration and tool wear and reduce surface roughness. In measurement of vibration, it was found that use of LDV is easy and it takes less time to measure vibration of work piece. Set up of LDV is easy when compared with set up of accelerometer.

Prof. L. B. Raut1 , Prof. Matin Amin Shaikh2, (2014) developed a model to simulate the vibrational effects of rotating machine parts on the single point cutting tool and cutting force acting on single point cutting tool in turning. In this paper experimental studies were performed on turning process & vibration is measured with the help of accelerometer along with a device called as Fast Fourier Transformer (FFT) Analyzer and cutting force is measured with the help of Tool dynamometer. This study concluded that the model of ANN can be predict the vibrations & cutting force of single point cutting tool at any three parameters such as spindle speed, feed & depth of cut. And this predicted value is nearly equal to actual value of vibrations & cutting force respectively. So with the help of ANN model we can easily predict the vibrations & cutting force of single point cutting tool without any experiment.

Sunilsing Rajput, Dr. D.S. Deshmukh, (2014), presented methods for the prediction of chatter. Analytical and experimental methods are presented in this paper for the chatter control which gives idea for the selection of optimal speed and depth of cut from the stability lobe diagram (SLD) and easiest method for chatter prediction is suggested. Stability lobe diagram is an effective tool which helps the operator to select specific spindle speeds for avoidance of chatter in machine. Stability lobes are plotted against axial depth of cut vs. spindle speed, which shows a boundary between stable and unstable regions. The vibrations in milling machines should be minimized for higher material removal rate (MRR). Chatter is the instability phenomenon must be avoided in milling machines by using stability lobe diagram. The main advantage of the chatter prediction through the stability lobes diagram is the metal removal rate maximization, at the same time avoiding the adverse effects of chatter vibrations like the poor surface finish, noise and breakage of tools.

Mahendra .U. Gaikwad, P.R. Kulkarni, (2013) carried out static and dynamic analysis of end mill tool with different geometry by Finite element analysis (FEA). Practical equations were developed to predict the static and dynamic properties of end mill tool. The results obtained by both the methods were found to be identical. It was seen that in case of static analysis amount of deflection of tool for a particular value of cutting force can be easily determined, while in case of dynamic (modal) analysis natural frequencies and mode shapes can be determined.

Yaser Hadi, (2012), presented a new approach for monitoring vibration during the machining process by regulating the periodic materials of the machine tool holder is presented. A digital dynamic simulation model was proposed to investigate the influence of periodic cutting tool holders as well as structural parameters on the stability of milling vibrations. The model written in MATLAB includes the contribution of the mass and stiffness and its affect on the cutting force amplitudes. The paper presents a new class of periodic machine tool holder system for isolating the vibration transmission from cutting tool holder to the machine tool table in an attempt to produce a quiet surface finish. A theoretical model is developed to describe the dynamics of wave propagation in a periodic tool holder. The model is derived using the theory of finite elements. The model of three periodic elements, spring steel-rubber, spring steel-copper and straight spring steel to compute the vibration amplitudes and forces are presented. The transfer matrix formulation for each element is given.

K. Reza Kashyzadeh,(2012), showed that there are some methods that can limit the chatter. They introduced and compared some of these methods, like regenerative, mode coupling, thermo mechanical and interrupted cuts. Further a brief analysis of the chatter modelling theory was also discussed.

S.S.Abuthakeer, et.al. (2011) conducted experiments on CNC lathe using CCGT-0930FL carbide turning insert, machining variables such as cutting tool vibration in tangential and axial direction were measured in CNC machining processes based on the vibration signal collected through a LabVIEW data acquisition system and controlled by using Viscoelastic material (VEM) neoprene. The effect of cutting parameters such as cutting speed, depth of cut and feed rate on machining variables is evaluated. The testing result showed that the developed method was successful. A multiple regression model has been developed and validated with experimental results. An analysis of variance (ANOVA) was made and it was found that the depth of cut (38% contribution), cutting speed (35% contribution) and Feed rate (27% contribution) has greater influence on cutting tool vibration. From the experimental results demonstrate that the depth of cut and cutting speed are the main parameters among the three controllable factors (depth of cut, cutting speed and feed rate) that influence the vibration of cutting tool in turning Al 6063 aluminum.

Marko Reibenschuh, et. al. (2010) compared different optimization methods, used for optimizing the cutting conditions during milling. It included also soft computer techniques in process control procedures. Showed that milling is a cutting procedure dependent on a number of variables. These variables are dependent from each other in consequence, if we change one variable, the others too changes. PSO and GA algorithm were applied to the CNC milling program to improve cutting conditions, improve end finishing, reduce tool wear and reduce the stress on the tool, the machine and the machined part. Further, on comparing two different approaches, it was concluded that one can implement soft computer techniques (optimization) to new technologies and materials. With the help of optimization tools one can reduce production time, improve end finishing by raising the quality and in the same time produce more parts. Apart from this the process control procedures are also very important, to assure proper functioning of the machining centre.

M Kayhan and E Budak, (2009), analysed the effects of cutting conditions as well as severity of chatter on tool life. The results indicate significant reduction in tool life on account of chatter, as expected. They also show that the severity of chatter, and thus the vibration amplitude, greatly reduce the life of cutting tools. These results can be useful in evaluating the real cost of chatter by including the reduced tool life. They can also be useful in justifying the cost of chatter suppression and more rigid machining systems.

Edouard Riviere, (2006) presented a dynamic simulation tool for milling operations. The main objective was to provide reliable simulations tool which is able to reproduce some test cases from the bibliography. This first step is validated using cutting forces, surface finish, stability lobes and frequency content of signal. Comparison with results from various authors shows a good agreement with the literature. Dynamic simulation thus is able to link results from different types of simulation and to reproduce typical instabilities arising in milling operation. Dynamic simulation of the milling process can be more adapted to analyze complex milling systems. Further, it was seen that these simulations can lead to a better understanding of the phenomenon of dynamic instabilities.

3. Conclusion

This paper presents a literature review of the study of various processes and techniques for analysing the machine tool vibration using different process parameters. This literature review is very useful, since it brings a better understanding of the field of study, and this is an important contribution of this paper. From the literature review it can be concluded that this subject attracts a great deal of interest by researchers.

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