Determination of Parameter and Minimization of Machine Tool Chatter

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Abstract

First, the development of the chatter vibration is observed using several turning tools having various cutting edge configurations and in the conditions in which there are different levels of interference between the flank of the tool and the work piece. Next, the exciting energy provided by the contact of tool flank and work piece is calculated using an interference model at the flank which includes an elastic deformation of work piece. In this review paper we consider on the parameter of machine tool chatter. Special focus is paid to the understanding on minimizing of machine tool chatter.

Keywords*: chatter, vibration, flank, turning, cutting.*

1. Introduction

Chatter is a nuisance to metal cutting and can be demonstrated on any chip-producing machine tool. The effects of chatter are all adverse and affect surface finish, dimensional accuracy, tool life, and machine life. Self-induced vibrations referred to as chatter frequently occur in metal cutting operations. Chatter is considered undesirable due to its detrimental effects. It has been the subject of many studies concerning both the mechanics of vibrations, namely, the dynamic cutting process and machine structural dynamics, and the methods of stability analysis using these relationships In the active chatter control of machine tools, the most effective way to suppress the chatter is to place the actuator as close as possible to the tool tip. Chatter vibration occurring in cutting operation impedes the improvement of cutting accuracy, the high speed cutting, and the unmanned operation of machine tools. Chatter vibration can be classified into two types The first type is called primary chatter vibration, which is caused by the falling cutting force characteristic, but mainly by the time lag of cutting force variation behind the cutting depth variation. The second type of chatter vibration is the regenerative chatter vibration, in which exciting energy is supplied by the phase lag between successive chatter marks on the workpiece. E. Budak et al. 2007 an analytical model for the prediction of the stability limit in turning and boring operations is presented. The model provides a multi-directional approach to the dynamic system by solving the stability limit in a matrix form. In addition the true geometry of processes, i.e. the important cutting angles and the insert node radius, are included in the model. It is presented that the stability limit solution for boring processes reduces to a 1D equation even with the nose radius model. The effect of important process parameters on the stability is demonstrated, and a comparative analysis is presented with the 1DOTF stability model. The model predictions are verified with chatter experiments and overall a close agreement is observed• richard y. Chiou et al. 1998. The chatter stability analysis in turning with this tool wear effect makes clear the behavior of the tool oscillation during chatter, and chatter stability can be explained qualitatively. It is based on the decomposition of the forcing function in dynamic machining systems in two contributing components: the cutting, and contact forces. The cutting force directly results from the chip load through the cutting stiffness. The contact force induced by the material displacement at the wear flat has been found to be related to both the cutting velocity and the plowing velocity of the tool at the work piece surface in the case of small amplitude vibration. A comprehensive expression of the equation of motion for the dynamic cutting system incorporating the effects of these contributing forces is established. Machining experiments were conducted on a conventional lathe with the use of a specially designed flexible tool which can only vibrate parallel to the feed and perpendicular to the cutting velocity direction. The machine characteristics and static stiffness were identified and the chatter stability were observed in verification of the analytical solutions over a range of cutting velocities and width of cuts. Among these cutting conditions, flank wear has been shown to have a significant effect on the chatter stability. T. Kaneko et al. 1984 Experimental observation of the behavior after the excitation of the self-excited chatter confirms that the vertical component has a slight phase lag behind the horizontal component in both the displacement and the cutting force. It was shown that this motion which supplies the vibration energy and maintains a stationary amplitude could be well simulated by the analysis of a two-degrees-of-freedom system with the multiple regenerative effect. The phase difference of the vibration occurring for each revolution of the work was instrumented between 30 and 90 deg depending on cutting conditions. It varies soon after the vibration starts; however, it stays constant after the excitation. It was shown that a significant variation of the pattern could be generated by a slight change of the frequency by assuming the wave form as sinusoidal and by considering the horizontal motion. The change of the frequency which caused the pattern winding from counter clockwise to clockwise was 0.13 Hz for 193 hz**e**mre Ozlu et al. 2007. A multidimensional analytical stability model for turning operations considering tool and work piece dynamics is formulated. The proposed analytical model includes the important parameters in the turning geometry, i.e., the practical tool angles and nose radius. a matrix solution procedure is developed for stability limit with the proposed elemental model for the insert nose. The basic stability model is applied to the boring operations in order to model its stability. Another solution method is proposed for the boring operations, which results in a 1D formulation with the same accuracy of predictions, but with a reduction of the computational time and the complexity of the solution procedure. The effect of important process parameters on the stability are demonstrated using simulations based on the proposed models. E. Marui et al. 1976. A result is ascertained that the cutting force lags slightly behind the cutting depth variation and also that the phase of the present chatter mark lags behind that of the previous cut in the regenerative chatter vibration. The apparent lag of cutting force in the regenerative chatter vibration is greater than that in the primary chatter vibration because of the chatter marks phase lag. The exciting energy which is determined by this phase lag and the vibratory locus of the work piece is supplied to the system, and the stable chatter vibration is maintained. In the practical cutting operations, first, the primary chatter vibration may initiate owing to the phase lag of the cutting force. After that, chatter vibration may be amplified by the regenerative effect. The stability boundary where chatter vibration initiates can be obtained. It is clarified that chatter vibration can effectively be eliminated in the system having large dynamic rigidity, for both primary and regenerative types.

2. Dynamics of orthogonal turning during chatter

Machine tool dynamics have been an important issue of interest amongst the machining community due to its significant role in the stability and other outcomes of the processes. The dynamics of the machine tool have great impact on chatter stability of the process. Whatever method is used for predicting instability, reliable results are only obtained when the dynamics of the structure and the cutting process are correctly incorporated in the method. Earlier chatter research done before 1990 focused mainly on cutting process parameters like speed, feed and depth of cut to be included in the dynamic models of the turning process. These models were unable to represent the true nature of machine tool dynamics and as a result the prediction accuracy was low. But over the last few decades (After 1990s), other new parameters like process damping, tool wear, tool geometry, stiffness of machine components, compliance between tool and work piece have been incorporated in the dynamic models of machine tool. These new dynamic models are very close to the real dynamic nature of the machine tool system and proved to be more accurate in predicting the stability/instability of the turning process. These new dynamic models are discussed in subsequent sections.
Regenerative chatter vibration arises due to the interaction between the metal cutting process and the machine tool structure and it is a major obstacle in achieving maximum material removal rate (MRR). Self excited chatter vibrations are much more detrimental to finished surfaces and cutting tools due to their unstable behavior which results in large relative displacements between the tool and work piece. Regenerative chatter occurs at the frequency of the most dominant mode of the machine tool structure. Excitation of this mode causes a relative motion between the machine tool and the work piece due to the tool cutting over a previously machined undulated or wavy surface. Chatter can be recognized by the noise associated with these vibrations, by the chatter marks on the cut surface, and by the appearance of the chips produced in turning. Machining with chatter is mostly unacceptable because of the chatter marks on the machined surface and because the large peak values of the variable cutting force might cause breakage of the tool or of some other part of the machine. Chatter is often a factor limiting metal removal rate below the machine's capacity and hence reduces the productivity of the machine. It would be a challenging task to identify/measure dynamic parameters of the dynamic chatter model. There are basically two approaches to formulate analytic expressions describing the turning process dynamics. The first has been to specify incremental cutting force equations of suitable form, and to derive the values of the coefficients of these expressions from steady-state cutting tests or by fitting to experimentally derived stability charts or by fitting the expressions to the results of dynamic/vibratory cutting tests. It is clearly much more straightforward to use steady-state tests, if a wide range of cutting conditions have to be investigated. A unified mathematical model was presented by Kaymakci et al. which can predict cutting forces for turning, boring, drilling and milling. This generalized model incorporates tool/cutter geometries of these multiple cutting processes according to ISO standards and predicts cutting forces considering oblique mechanics. The model seems quite promising because it can even be used to develop unified chatter stability laws for multiple operations.

3. Analytical techniques for chatter stability prediction

Various techniques are available in the literature for the analytical prediction of chatter stability conditions. Among them, construction of SLD. Shows the number of publications for each technique. It should be noted that multiple citing is possible as some publications may repeat in each category. The construction of SLD is the most popular technique among researchers because of its simplicity and clarity in defining stable and unstable cutting states. The SLD can be produced for mathematical models containing any number of DOF (degrees of freedom) cutting processes.

5. Conclusion

The paper summarizes the state of research knowledge in dynamics of metal cutting and grinding operations. Since orthogonal chatter stability laws in 1950s, significant progress has been made in modeling machining processes. The frequency domain chatter stability laws in high speed milling have been well developed and used in industry effectively. Significant research efforts have been reported in time domain modeling of turning, boring, milling and grinding operations which allow the analysis of dynamic machining when the machine tool and work piece stiffness, work material, tool geometry and cutting conditions are varied. The frequency and time domain simulation models are effective tools to improve machine tool design and for optimal planning of machining operations. There are still unsolved research challenges in dynamic cutting and grinding. The solution of chatter stability for tapping, gear shaping, broaching and parallel machining have yet to be developed for practical use in industry. The chatter stability is still not solved when the process is highly nonlinear due to time varying and nonlinear cutting coefficients including the process damping at low speeds, and when the structural dynamics of the parts and machines vary along the tool path. It is most desirable to integrate process simulation and chatter stability algorithms directly to cad /cam systems so that the machining operations can be optimally planned and tried in a virtual environment before testing them on costly trial cuts on the shop floor.

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