A Review on Prediction of Chatter Stability in High Speed Milling

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Abstract- *This paper reviews on the various analyzing techniques of chatter stability in high speed milling. Milling at high spindle speed is an effective technology for processing various materials. During milling, unstable selfexcited vibrations known as regenerative chatter can occur, causing excessive tool wear or failure and a poor surface finish on the machined work piece. There are several analyzing techniques that are used to increase the stability of the machining process such as stability lobe diagram (SLD), Structural dynamic modification. Based on these analyzing techniques how the operating variables are changed to obtain the different predicted results is studied.*

Keywords- chatter, spindle speed, dynamic modeling, FEA.

I. INTRODUCTION

High speed milling is extensively used in manufacturing process. The generation of complex shapes with high accuracy and quality is the main advantage of milling process. In a real world setting there are many variables that influence a machining process and each one can carry small errors or uncertainties, which can lead to major deviations in the finished quality of fabricated parts. It therefore becomes important to research novel models to account for parameter uncertainties in order to develop more practical models.

During milling process a self-excited vibration called chatter will occur that may leads to poor surface finishes and limits the efficiency and productivity of machining operations through a loss of dimensional accuracy, a reduction in the longevity of the tool, and damage to the tool or work piece. It originates from coupling between cutting force and vibration of tool-work piece system.

The recent trend towards the high speed and high precision cutting process requires accurate modelling. In milling process, accurate prediction is great significances to effectively avoid the occurrence of chatter. Prediction of stable machining parameters was a critical job. Due to time-verifying properties and complicated structures of the cutting system, chatter has become one of the most unexpected and uncontrollable phenomenon during milling operation. With the rapid development of high speed milling, this problem becomes more and more prominent. The purpose of this study is to review on various method of proposed prediction.

Prediction: Machining is one of the most important and widely used manufacturing processes. Due to chatter stability of the machining processes, soft computing techniques are being preferred to physics-based models for predicting the performance of the machining processes.

Predicting Techniques: In this study stability lobe diagrams, edge theorem, finite element simulation, dynamic structural modeling are observed.

Prediction process parameters: The milling is characterized by a large number of operational parameters which determine the efficiency, economy and quality of the entire process. In general, the parameters in milling can be divided into three categories: 1.Process parameters 2.Acceleration parameters 3.Cutting parameters.

Mohammad R. Movahhedy et al [1]: In this paper both structural and cutting force non-linearities prevented. It is derived through Fourier series. One more decay and specific conditions. It is possible to suppress undesirable vibration of one mode in which surface finish is accurately required by application of internal resonance and steady state jump phenomenon is investigated. It is possible to transfer energy under regenerative chatter condition jump phenomenon is investigated. Transfer of energy between x and y mode is studied under internal resonance. Nonlinear cutting forces are derived through Fourier series.

S.S.Park et al [2]: In this paper robust chatter stability which is based on edge theorem is employed to provide the robust stability within the minimum and maximum boundaries of changing parameters. The robust stability with the process damping shows increase in the critical depth of cut at lower spindle speeds compared to the analytical stability. At higher spindle speed the valleys of the waves are narrower since the frequency of the cut waves are higher resulting in fewer process damping effects.

Tojiro Aoyama et al [3]: This paper discuss about monitoring chatter vibrations by using additional sensors such as acceleration sensors are generally used. High cost and low reliability of machine tools. Does not require any external sensors instead uses servo information of spindle control system.in this study we developed a novel method to detect chatter vibrations in milling and evaluated its validity by carrying out several milling tests Fig(1).

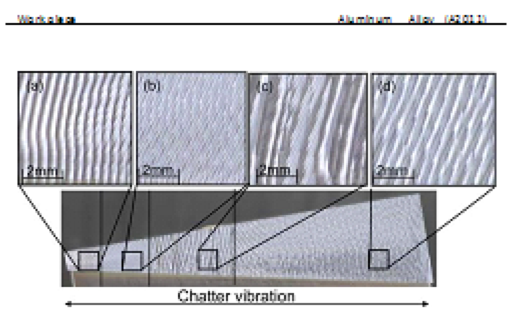

Fig.1. Machined surface after milling test.

The results are summarized as follows.

1. Average T method can measure the angular velocity with the higher accuracy than conventional m&t methods
2. The wave form of the measured disturbance torque changes according to the type of chatter vibrations. FFT analysis of the disturbance torque shows that behavior of the chatter vibrations up to 2 KHz becomes remarkable when the axial cutting speed increases.
3. The discrimination method using digital filtering is proposed separately detect self-excited and forced types.

EijiShamoto et al [4]: This research presents novel strategies to optimize tool path /posture to avoid chatter vibration in various milling operations. The simple index is proposed to represent machining stability due to tool path/posture. A novel concept is proposed structural matrix and specific cutting force are given. The gain margin and stability limit are calculated. Useful research and development environment to optimize tool path. Affective in CAM automatic programming system.

ErhanBudak et al [5]: This paper details the work piece dynamic effect stability in machining of flexible part. It is not a straight forward task as dynamic, continuously changes due to massremoval and variation of cutter contact. Cutter location (CL) file is used to determine removed elements at each tool location along a cycle. Analytic method is proposed for modeling of varying work piece dynamics. Methods based on FE mesh, CL method is used to tool path information. It shows that natural frequencies vary with material removal.

Jokinmunoa et al [6]: In this paper chatter vibration coming from the machine tool structures are a major limitation for a heavy duty milling operations .Passive and active dampers can be added to increase the productivity. Cost and space are drawbacks .Machine tool drives are used to suppress chatter with the help of an external accelerometer located close to tool center point.

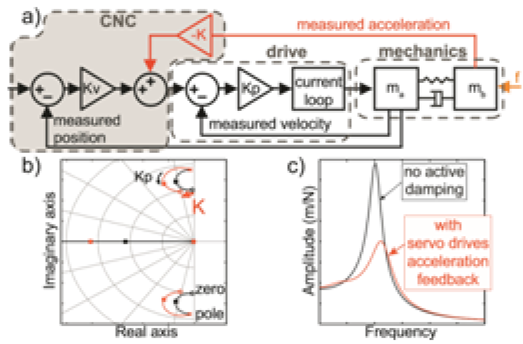

Fig. 2. Vibration damping by velocity set point acceleration feedback: Control diagram, (b) velocity loop root locus and (c) tool tip compliance

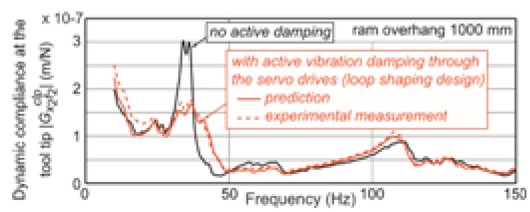

Fig 3: Tool compliance without and with active vibration damping (a)

The measured acceleration is fed back as additional control loop Fig (2) &Fig(3). The paper has prevented due chatter suppression method able to actively damp out the structural modes of a large milling machine tool own feed and low cost accelerometers. Factors like sensor or chatter stability, sensor noise, dynamics are considered. Productivity increases by 85 and 600% by suppressing structural chatter.

Evitaedhi et al [7]: Energy equilibrium equation is used for predicting the stability borderline in terms of cutting conditions. If the borderline is above the cutting condition, then chatter should occur. Some parameters are also predicted like vibration of tool tip using computation. Transition from the border line to the condition above the border line has been evaluated by predictive calculation of time phase between x and y vibration displacement. Validity of border line, width of cut, and x to y amplitude ratio are confirmed by comparison with experimental measurement obtained in cutting test.

Norikazu Suzuki et al [8]: This prevents a transfer function by utilizing immerse analysis of excited chatter vibration measured during an end milling experiment. The transfer function can be identified to minimize the errors between chatter analysis and experimental result. The basic end milling test verifies that the transfer function identified by the developing method is similar to the measured impulse response method. It yields a more accurate prediction of the stability limits

V.Gagnol et al [9]: Prediction of stable cutting region is a major requirement for high speed milling operations. These predictions are generally performed using frequency response measurements of the tool or holder or spindle set. However significant changes in dynamics occurs during high speed rotation. In this paper, a dynamic model of high speed spindle bearing system is elaborated Fig (4).

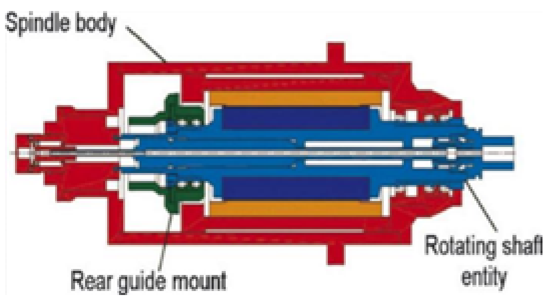

Fig. 4. The HSM spindle bearing system.

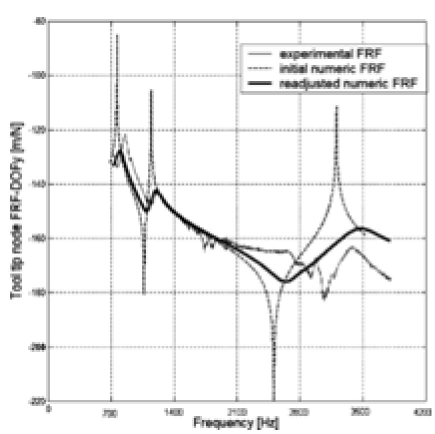

Fig. . Experimental, initial and readjusted FRF.

Variations in dynamic behavior according to speed ranges are investigated and accurately determined. Finally experiments are performed in order to validate chatter boundary predictions in practices Fig (5).

M.R.Movahhedy et al [10]: Prediction of chatter vibration and investigation effect of various conditions on the onset of approach this uses finite element simulations investigate between the chatter vibration and chip formation process .mesh adaptation technique is used to move the tool inside the wok piece to form the chip. While the flexible tool is used to allow it to vibrate under variable loading conditions. This simulation is able to predict various phenomena in actual machining process like variation of shear angle and increase of stability at low speeds.

Weihongzhangetal [11]: The investigation is on the effect of varying work piece dynamics in the stability in peripheral milling of thin walled work pieces with closed surface .An efficient method based on structural and dynamic modification scheme is developed to characterize the effect of material removal upon the work piece dynamics. Modal analysis is performed on the FEM mode of initial work piece. The model and the method is verified by milling of two thin walled work pieces of a plate and a work piece with a curved surface .Comparison between experimental and numerical results show that chatter can be predicted accurately Fig(6).

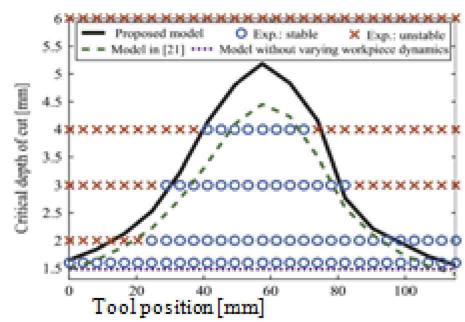

Fig. 6. Comparisons of stability borders obtained by different models.

N.Grossi et al [12]: Chatter prediction is affected by depending on the data entry that is cutting forces and frequencies. The evaluation of specific cutting force in high speed milling is a challenge because of frequency bandwidth in commercial force sensors. Here specific coefficient have been identified at different spindle speeds. Obtained speed coefficients have been used to improve the stability lobe diagram for High Speed Milling.

II. CONCLUSIONS

From this review we conclude that chatter occurrence reduces the surface finish, dimensional accuracy of the work piece and it imposes limit on the production. To overcome this effect of vibration both theoretical and experimental methods to predict chatter stability are followed. The theoretical methods are generally stability lobe diagram, edge theorem dynamic modeling and finite element simulation which are used to calculate the uncertainties parameter and work piece dynamics. The experimental techniques include disturbance observer, spindle bearing system, force sensors, dampers etc. By conducting several milling test different studies are made over the chatter prediction. Prediction of chatter stability is not a complete solution to get rid of the regenerative chatter, it is one of the significance to reduce the chatter vibration. By predicting the chatter stability we can reduce the effect of chatter vibrations and may improve the efficiency of the milling process.

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