# A Review on Investigation of Stability for High Speed Spindle Machining Centre

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## ABSTRACT

High Speed Spindle milling have found wide range of application in aerospace, engine components in order to improve the stability by eliminating chatter vibrations, where the work piece is considerably more flexible than the machine-tool system. Over the years though a lot of work has been done to address this issue there is still huge scope for improvement in high speed machining centers .This paper identifies the various factors causing stability and affecting the quality of the milling and providing general recommendations for the selection of different process parameters such as material properties, tool geometry, cutting conditions, vibration parameters and also the frequency characteristics of machine tool-system of the high speed spindle milling for the better quality of finish

**Key words:** Milling, Stability Lobe Diagram, Chatter, Spindle, Stability.

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## INTRODUCTION

The major performance features are spindle power, peak and continuous, maximum spindle speed, speed allowed, tooling style, size and capacity of the machine. High speed milling has assumed as importance and become more versatile industry application in fulfilling the requirements of high productivity and better quality due to increase demand and cost reduction in manufacturing. It is typically refers to making light milling passes at high spindle speed and feed rate to achieve a high metal removal rate. High geometrical accuracy low cutting forces are among the advantages of high speed machining that finds applications mainly in aerospace and die and mold industry. The term "high-speed machining" (HSM) is a relative one from a materials viewpoint because of the vastly different speeds at which different materials can be machined with acceptable tool life.

### AUTHOR'S VIEW

### Chigbogu Godwin Ozoegwu et al [1]:

This paper presents the concept of using bi-radial immersion to improve the stability of 3 axis end-milling operation. The combined-mode effect gives better results when compared with the ordinary milling operation. The combined-mode end-milling is the combination of conventional milling (i.e. both up milling and down milling). At various spindle speeds it produces stability boundaries and curves that is most appropriate for this 3-axis end milling. It produces very high material removal rate (MRR) per active pass and very low surface finish during finish slotting. By combining the size and location of pre-existing slot which elevates the stability resulting in lobbing effects. For getting good finish in slotting we can go for multi spindle system with pre-slotting tools which will improve the stability and also reduce the manufacturing time. Thus providing continuously varying spindle speed at different depth of cut gives the stable and unstable lobbing effects that can be shown below in the form of diagram for bi-radial immersion i.e. for both up milling and down milling.
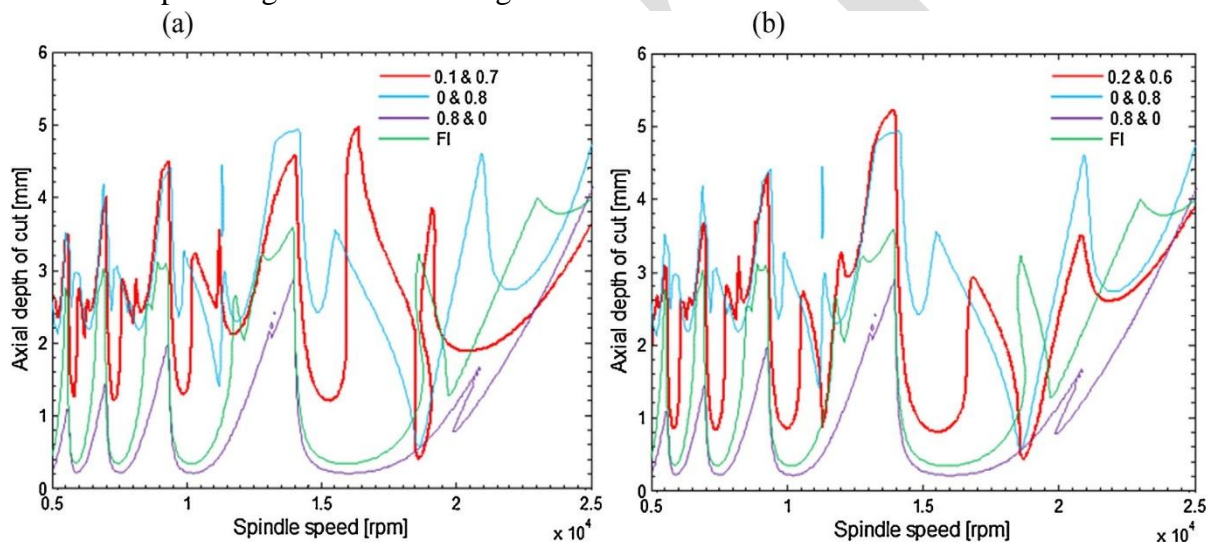


**Fig-1**. Stability transition curves of the bi-radial immersion cases with effective radial immersion $\rho = 0.8$ are placed on same axis as those of both cases of up end-milling (purple) and down–end-milling (blue) corresponding to $\rho = 0.8$ and the full-immersion case (green). The component radial immersions of each bi-radial immersion case (red) are contained in the legend where the first numerical value corresponds to 1 and the second numerical value corresponds to 2. (a) $\varepsilon_{1,2} =$ 1.8 mm, (b) $\varepsilon_{1,2} = 1.2$ mm.

### A. Iglesias et al [2]:

This paper describes the self-excited vibrations created during the milling process affects the tool life and stability of the process. The analytical expressions are used to solve the chatter occurrence and to improve the stability of the milling in one-dominant mode. The analytical methods including semi-discretization, Delay differential equation and zero approximation model are used to predict the stability and chatter prevention. The double period chatter and flip lobes are the two effects which causes the improvement of the milling. By the numerical iteration

we can solve double period chatter but is not solved fully though. The large immersion give inaccurate solutions due to flip lobes. The frequency of chatter and depth of cut in the flip lobes can be predicted only at the minimum condition. By selecting the proper cutting tool and the spindle speeds we can maintain the tool life and getting accurate results.

### Chong Peng et al [3]:

This paper explains the chatter which slow down the stability and productivity of the machining process. In order to avoid the chatter problem, a new method is secured on dynamic cutting force simulation model along with support vector machine (SVM) for the conjecture of stability lobes. The cutting data will be imitative from the MATLAB LIBSVM toolbox. The emulated cutting force signal from the SVM machine which clearly shows the chatter occurrence and to analyze the spindle speed in critical axial depth. The stability lobe diagram (SLD) provides useful way to avoid cutting chatter in the process. By using these above techniques we can improve the stability and to eliminate chatter problem finally it results in reducing the manufacturing time.

### Sun Chao et al [4]:

In this paper with the use of automated balancing of tool axis orientation to avoid chatter as well as cutting tool path in the free form surfaces of 5-axis ball-end milling operation. In this technique the tool axis directions are aligned in such a way to prevent strike with the work piece and tool tip at zero speeds for this 5-axis ball-end milling. The chatter is caused mainly due to the flexibilities of the tool and their parts. By re-orienting the tool axis diverts the cutting force of the tool which stay from the chatter occurrence. Thus the stability of the end milling can be found iteratively by NY Quist criterion. To avoid the collision and gouging of the tool we go for this tool orientation with the limited extent. By merging the 5-axis tool path generation with computer aided manufacturing (CAM) will improve the productivity and surface quality of free form surfaces and machining dies and molds.

### Rusinek Rafal et al [5]:

This paper focuses on the process stability of the tool machine system in milling. Based on time series method the chatter occurs only at the unstable region of the Ti6242 titanium alloy milling process. The SLD created using the cutpro9 software is found higher when compared with the other experimental results such as recurrence plots, Hilbert-Huang transform and statistical parameters. The general method analysis when implemented to cutpro9 is not an effective method for predicting instability. Thus the recurrence plot measures will give the suitable results for prevention of chatter and the improvement in stability of the milling process.

### Etienne Gourc et al [6]:

This paper work gives a detailed information about the modelling of active magnetic bearing spindle (AMBS) at high spindle speed up to 40000 rpm corresponding to first hoop and flip lobes. The self-excited vibrations was generated due to the tool thickness and the tool's vibrations. If the forced vibrations were so strong then the spindle will automatically stopped. Indirect measurements of vibrations with the control signals of bearing spindles will finally give efficient means to assess the stability of the machining.

### S.M.Afazov et al [7]:

This paper presents the prediction of stability lobes by considering the run-out effect, dynamics of tool-holder assembly. The run-out effect may be caused from the FE model of orthogonal

cutting. Scanning electron microscope (SEM) inspection has been at various spindle speeds and depth of cut to found chatter marks. The spindle speeds higher than 35,000 rev/min have predicted stability limits on the modal parameters which influences stability lobes in micro-milling. By higher cutting forces and the feed rate the stability area decreases. The spindle speeds at 32,000 rev/min shows good results in micro-milling process. Therefore by increasing the run-out length per tooth feed rates of the operation provides stability areas between 4 and 8μm respectively. These techniques can be used to improve the stability of the milling by minimizing the chatter.

### Hongrui Cao et al [8]:

This paper discusses the chatter stability of the machine tool mainly depends on the dynamic behavior of the spindle system. By considering the speed-varying spindle dynamics to predict the chatter stability lobes of high speed milling. The gyroscopic moment of the spindle shaft will increases the cross frequency response function (FRF), but it surely affects the tool tip due to the damping of the spindle system. The centrifugal forces on the shaft and bearings minimize the overall spindle system stiffness when increasing the speed. The chatter stability with respect to speed effects shift to low speed ranges will gives the stability lobes can be predicted easily at various spindle speeds of milling operation.

### N. Grossi et al [9]:

This paper works revolves around the cutting force coefficients and machine tool dynamics that provide change at different cutting velocities based on this chatter stability occurs. The parameters influenced by spindle speed due to high speed machining (HSM) and frequency response function (FRF). By implementing a speed-dependent stability lobe diagram is used to improve the reliability of chatter prediction. The accurate stability lobe diagram are useful in HSM by increasing spindle speed at high depth of cut for increasing productivity. The tool-tip dynamics and the cutting force coefficients becomes crucial to improve the performance of milling.

### Ramin Rahnama et al [10]:

This paper focusses mainly on the regenerative chatter created in micro-milling which causes tool life and breakage reduces the stability and productivity of the milling. The process damping is due to the tool movement of work piece, tool geometry and cutting conditions, such as chip thickness, clearance and effective rake angles. By predicting the suppression of regenerative chatter is critical, in order to maintain the longevity of the tools, to ensure the dimensional accuracy of machined parts and to reduce the excessive burr formations. The stability increases as rotational spindle speed decreases due to process damping which is observed in chatter stability tests.

### K. Ahmadi et al [11]:

In this paper the Semi-Discretization Method (SDM) is used to model the chatter in peripheral milling using cutters with helical teeth. This method is used to determine the stability of the cut and establish the stability lobes. Normally the stability lobes are found at specific feed rate, feed direction and tool geometry these parameters are constantly throughout the toolpath. These stability diagrams are established for 5-axis peripheral milling of three surfaces. The process damping is also developed in this work. The Stability Maps which is related to stability lobes where it shows stability along the tool path and work piece geometry engagement versus spindle

speeds. While machining in the curved surfaces to avoid chatter in the tool path. Thus giving proper feed and tool radius we can improve the chatter as well as the stability of the milling.
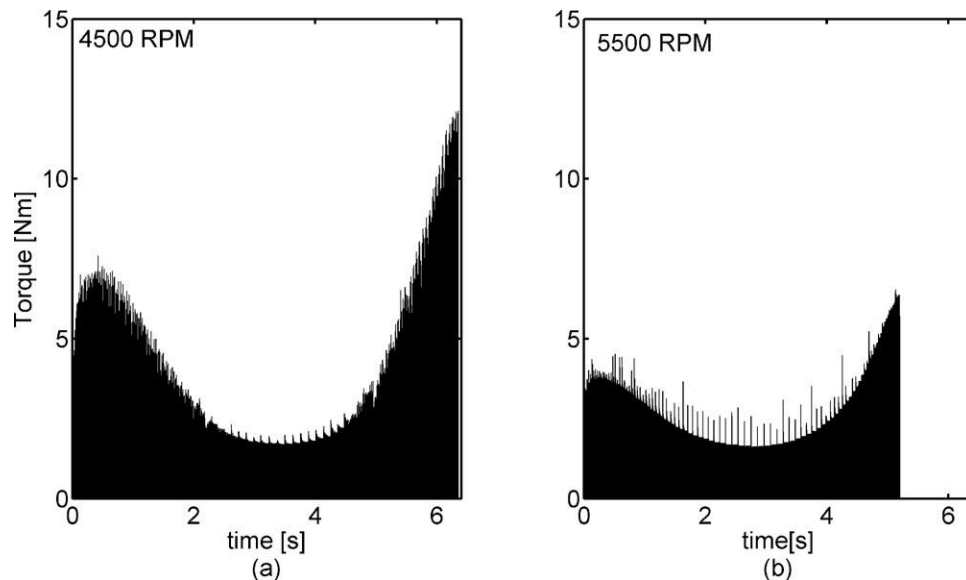


**Fig-2**. Numerically simulated torque while machining surface 2 height of 15mm with (a) 4500 rpm, unstable at the beginning and end of tool path, and (b) 5500 rpm, stable along the full toolpath.

## Min Wan et al [12]:

This paper discusses the chatter stability of the milling process with multiple delays under different cutting force models. This can be induced by using cutter run-out. The instantaneous cutting force of uncut chip thickness which gives the prediction of stability lobes .The methods used are based on the vibration time history of the cutter motion, which is obtained by time domain simulation. The cutting force coefficients calibrated with different feed per tooth for the accuracy of the cutting force's coefficient. The calibration accuracy and cutting force model have great influence on the reliability of the stability lobes.
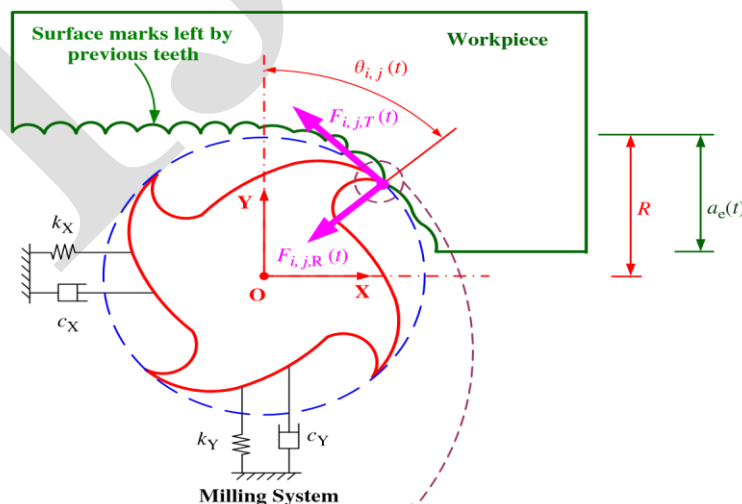


**Fig-3.** Schematic mechanical model of a two degree of freedom (DOF) milling system (illustration for a 4-fluted cutter).

Thus providing the dampers on the cutter in the x and y direction, we can reduce the vibrations and also the stability can be improved. So that by providing the number of dampers we can arrest the vibrations and also the longevity of the cutter in the tool machining system. This can be done by using the degree of freedom technique and simplified time history of vibration signals.
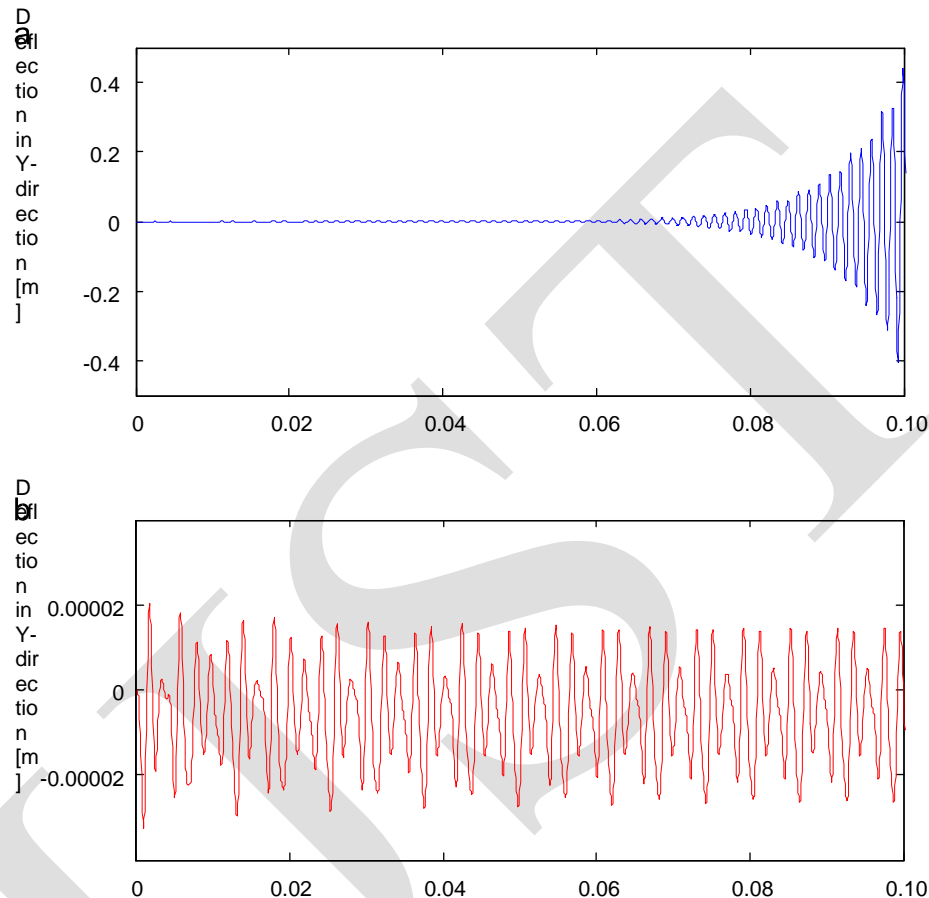


Fig.4. Time history of vibration deflection signals after ignoring the instantaneous variation of entry and exit angles. (a) Unstable milling case and (b) stable milling case.

**Antonio Scppia et al [13]:**

This paper presents the milling process plan based on the finite element method (FEM) for thin walled parts. The stiffness play a major role in any components but in the thin walled structures can be obtained from the bulky parts (monolithic). In this method stable cutting process and the vibrations occurs due to the high removal rate (i.e. high feed, large depth of cut) and low stiffness. To increase the productivity to a greater extent we must also increase the material removal rate also. In order to reduce the deflections and vibrations we must consider the effects of tooltip, material removal. Moreover continuously varying the spindle speed may improve the stiffness and the chatter stability of the milling operation. Using this FEM we can able to select the proper feed and spindle speed along the tool path, by reducing the relative displacement between the tool and work piece in order to improve the accuracy of complex thin walled parts.

### I. Bediaga et al [14]:

This paper mainly focusses on the stability of high speed milling to detect the chatter occurrence for that we have to constantly varying the spindle speed. To reduce the vibration formed in the high speed rough milling operation we go for automatic spindle speed selection strategy when high material removal rate is maintained. The portable digital assistant (PDA) will be implemented to detect and diagnosis of chatter. This device is operator-friendly because of its mobility. This device give immediate response, provide the right speed to avoid the chatter vibration supplied in fraction of seconds. The PDA not only minimize the machining time but also increases the productivity. With the help of these devices we can easily analyse such problems in the automatic spindle speed.

### O.B. Adetoro et al [15]:

This paper presents the improved prediction of stability lobes using non-linear thin wall dynamics. The accurate prediction of stable cutting conditions is found thinner due to weightier components. If the component is thinner it greatly reduces the structural stiffness of a part. By considering varying dynamics along the thin wall section to gain stability using FEA approach. The tool/cutter function can be constant but the work piece function cannot be constant. Thus preventing the chatter we can improve the surface finish, productivity and cost in damage to repair. Using the number of dampers will also improve the stability and the other parameters of the machining process.

### CONCLUSION

From this review it can be concluded that the chatter occurrence and vibration reduces the surface quality, surface damages of work piece, productivity, dimensional integrity and machining stability. Therefore selecting proper feed and depth of cut improves the stability of the milling operation. Providing dampers must prevent the vibrations thus increasing the stiffness of the part while machining. For the thin wall parts we cannot go for high material removal rate (high feed, depth of cut) which can reduce the stiffness of the part. Stability cannot be easily predicted for that we use continuously varying spindle speed. The centrifugal forces having higher overall spindle system stiffness but the speed can be reduced. By selecting suitable cutting conditions, tool geometry, and the spindle speed we can get the accurate predictions of vibrations and chatter.

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