PREDICTION OF CHATTER IN MILLING

[1.]M.M. RAVIKUMAR, [2.]A.BHASKAR

[1.]Department of Mechanical Engineering, Pallavan College of Engineering, Thimmasamudram, Kanchipuram -631502, Tamilnadu, India

[2.]Department of Mechanical Engineering, Pallavan College of Engineering, Thimmasamudram, Kanchipuram -631502, Tamilnadu, India

ABSTRACT

The machining industry has an increasing need for improved characterization of cutting tools for controlling vibration and chatter during the milling process. The chatter is a self excitation phenomenon occurring in machine tools, in which the cutting process tends to decrease the machine structural damping ending with an unstable behavior. The paper is organized as follows: In section 1, the differential equations describing the mechanical model, In section2, the experimental setup and finally, the conclusions are drawn in 3.

KEY WORDS: *Chatter, Mechanical Model, Critical Damping, Experimental Setup.*

1. INTRODUCTION

In recent trends of manufacturing industry, the high speed machining, especially high speed milling plays an important role. Few examples are the fabrication of moulds and aerospace industry, where large amount of material are removed form a large structure. The milling process is most efficient, if the material removal rate is as large as possible, while maintaining a high quality level. The most critical limitations in machining productivity and part quality are the occurrence of the instability phenomenon called regenerative chatter. The chatter is a self excitation phenomenon occurring in machine tools, in which the cutting process tends to decrease the machine structural damping ending with an unstable behavior. It results in heavy vibrations of the tool causing an inferior work piece.

2. MECHANICAL MODEL

Figure.1 shows the simplest two degrees of freedom model of highly interrupted cutting and the milling cutter as a flexible system, with the stiffness and damping elements oriented in the X and Y directions [2]. Assuming, that the machine tool structure has multiple modes, let M, C and K be the generalized m x m mass, damping and stiffness matrices of the structure.

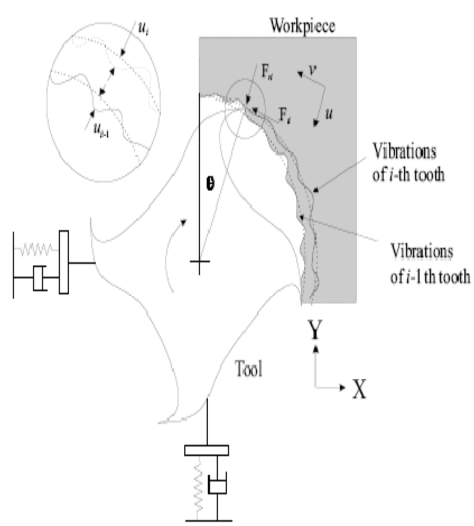

Figure .1 The Standard Two Degrees Of Freedom

Assume the tool to be flexible relative to the rigid work piece. The two degrees of freedom oscillator is excited by the cutting work piece. The dynamic governing equation has the form [3].

$$\mathbf{M\ddot{x} + C\dot{x} + Kx = F}$$
…….. (1)

Where M, C and K are known as the mass matrix, damping matrix and stiffness matrix respectively. Where the force vector f = [f_x, f_y] t is acting.

If forces are not supposed to act on the mass, then the eqn (1) can be written as

$$\mathbf{M\ddot{x} + C\dot{x} + Kx = 0}$$
…… (2)

The above equation is called the characteristics equation of the system and the Differential Equation is of Second Order in X.

Assuming a Solution of the form

$\boldsymbol{X = e^{ut}}$ Where u is the constant to be determined.

Then

$$\dot{\mathbf{x}} = \boldsymbol{ue^{ut}}$$
$$\ddot{\mathbf{x}} = \boldsymbol{u^2e^{ut}}$$
...... (3)

Substituting the values the of $\dot{\mathbf{x}}$ and $\ddot{\mathbf{x}}$ in the equation (1), we get

$$\boldsymbol{mu^2e^{ut} + cue^{ut} + ke^{ut} = 0}$$ or

$$\boldsymbol{u^2 + \frac{cu}{m} + \frac{k}{m} = 0}$$
…… (4)

Solving the above equation for u, we get

$$\mathbf{u = \frac{-c/m \pm \sqrt{c^2/m^2 - 4k/m}}{2}}$$

$$\mathbf{u = -c/2m \pm \sqrt{(c/2m)^2 - k/m}}$$

…… $(\mathbf{5})$

The two roots can be written as

$$\boldsymbol{u = -\frac{c}{2m} + \sqrt{(c/2m)^2 - k/m}}$$

$$\boldsymbol{= -\frac{c}{2m} - \sqrt{(c/2m)^2 - k/m}}$$

… $(\mathbf{6})$

Now the solution of the equation (1) can be written as

$$\boldsymbol{x = A_1\, e^{u_1\, t} + A_2\, e^{u_2\, t}}$$
….. $(\mathbf{7})$

where a_1, a_2 are two arbitrary constants and u_1, u_2 are its two roots. This equation can be written as

$$\boldsymbol{x = A_1\, e^{[--\frac{c}{2m} + \sqrt{(\frac{c}{(2m)^2} - \frac{k}{m}}]t} + A_2\, e^{[--\frac{c}{2m} - \sqrt{(\frac{c}{(2m)^2} - \frac{k}{m}}]t}}$$

… …. $(\mathbf{8})$

3. CRITICAL DAMPING

The critical damping c_c is defined as the value of damping coefficient c for which the mathematical term $\boldsymbol{[c/2m]^2\text{-}k/m}$ in equ (8) is equal to zero.ie.

$$C_c = 2m\,\omega$$

The ratio of c to c_c is termed as damping ratio. It is indicated by the symbol ε. Mathematically it can be written as $\varepsilon = c / c_c$

Let us the consider the term c/2m of equ (8)

$$\boldsymbol{\frac{C_c}{2m}} = \varepsilon\,\omega$$
…. (9)

So equ (8) can be written with the help of equ (9) as

$$\boldsymbol{x = A_1\, e^{[-\varepsilon + \sqrt{\varepsilon^2} - 1]\omega t} + A_2\, e^{[-\varepsilon - \sqrt{\varepsilon^2} - 1]\omega t}}$$
… …. (10)

The nature of the system depends upon the value of damping. Depending upon the value of damping ratio, the damped systems are put in to three categories which are as follows:

Over damped system: when damping ratio ε is more than one i.e. ε >1. This motion is called a periodic. When t = 0 the displacement is the sum of A_1 and A_2 .i.e.

$$A_1 + A_2.$$

Critically damped: the system is critically damped when ε = 1. The roots of the equation $u_1$and u_2 are equal to each other.

$$u_1 = u_2 = -\,\varepsilon\,\omega = -\,\omega.$$

So the approximate solution of equation may be written as

$$x = A_1\, e^{-\omega t} + A_2\, e^{-\omega t} \quad \text{....... (11)}$$

In the above equation A_1 and A_2 are the arbitrary constants whose values can be determined from initial conditions as in case of over damped system.

Under damped system: In this case the value of damping ε is less than unity. The roots of the equation can be written as

$$\mathbf{u_1} = [-\boldsymbol{\varepsilon} + \mathbf{j}\sqrt{\mathbf{1} - \boldsymbol{\varepsilon}^2}\,]\boldsymbol{\omega}$$

$$\mathbf{u_2} = [-\boldsymbol{\varepsilon} - \mathbf{j}\sqrt{\mathbf{1} - \boldsymbol{\varepsilon}^2}\,]\boldsymbol{\omega}$$

Where

$\boldsymbol{j} = \sqrt{-\mathbf{1}}$ Where

j is the imaginary unit of complex roots.

4. EXPERIMENTAL SETUP

This approach gives a more accurate picture of the tool cutting ability but requires extensive testing.

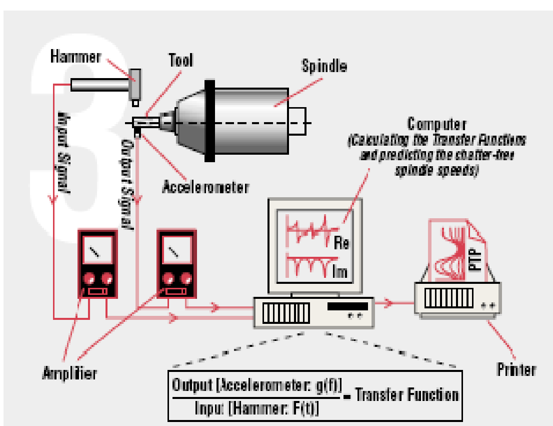

Figure .2 Experimental Set Up Of Chatter Prediction

5. PREDICTING METHOD

Figure.2 shows the schematic setup for determining the chatter free spindle speeds. A piezoelectric instrumented hammer is used to apply a short force pulse to tool system [1]. On the other side an accelerometer is attached to the tool tip, which measures the vibration displacement caused by the hammer impact. Both signals are then amplified and sampled. The transfer function, which describes the dynamic characteristics of the tool is then computed and used to calculate the sweet spots for a certain work piece material and cutting conditions.

6. RESULTS & DISCUSSIONS

By predicting method, we can determine the occurrence of chatter though the work piece is already damaged. The figure.3 shows the chatter prediction of an end mill (aluminum) 0.75" in which the analysis are carried out by using lab view automation software. The vibrations are analyzed with respect to their frequency and amplitude during dynamic conditions.

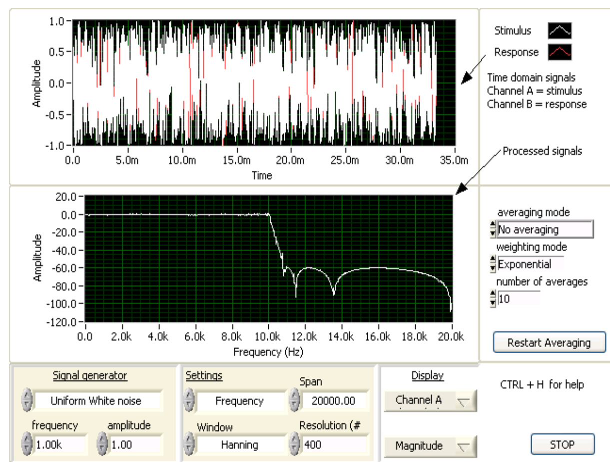

Figure .3 Chatter Prediction Diagram of 0.75"Endmill

7. CONCLUSIONS

A mechanical model was used to derive the equation of motion. The theoretical results can be calculated by using the differential equation (1) and the other method was supported by experimental tests. From the software analysis, two main observations shows how at some speeds the cut is stable and cutting forces are low, while at other speeds chatter dominates and the peak cutting forces are high for an end mill.

REFERENCES

[1]. Tlusty.j. Olacek.a, Danek.c, Spacek.j, 1962, Selbsterregte Schwingungen an werkzeugmaschinen VEB Verlag Technik, /Berlin.

[2]. Tamas Insperger, Janez Gradisek" Machine Tool Chatter and Surface Location Error in Milling Processes" Journal of Manufacturing Science and Engineering , Nov 2006, vol.128

[3]. V.P.singh., Mechanical Vibrations, Dhanpat Rai & Sons, Chandigarh.