12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

THE ASPECTS ABOUT DYNAMIC MILLING MACHINING PROCESS

Petru A. Pop
University of Oradea
1 University Str., 410087, Oradea
Romania

Gheorghe Bejinaru-Mihoc
"Transilvania" University of Brasov
29 Eroilor B-rd, 500036, Brasov
Romania

Petru Ungur
University of Oradea
1 University Str., 410087, Oradea
Romania

ABSTRACT
This paper has presented certain aspects about dynamic machining process, in special at milling process. The study of dynamic machining process is done by the analyzing of interaction between elastic structure (SE) of machine tool and cutting process (PA), at traditional machine tools and machine tools with adaptive control. An important factor which has direct influences about dynamic machining system is occurring vibration, in special at chatter frequency, which due to real perturbation and damages to dynamic machining system. The main cause of vibrations occurring has due by dynamic interaction of cutting process and machine tool structure. For analyzing of dynamic machining process it's necessary determination of stability diagram, by using a dynamic installation for determination of cutting forces, vibrations and critical depth of cut for all spindle speeds of machine and get the solutions for enhanced the dynamic stability of system.
Keywords: cutting process, dynamic machining system, elastic structure.

1. INTRODUCTION
Today, the dynamic market of manufactures has required machining systems that provide low cost, higher quality and highly responsive solutions. Responsiveness includes the capability to react to changes in volume capacity as well as changes in part mix or functionality, referred to here as scalability and convertibility. This will allow for a comprehensive evaluation of the impact of manufacturing system configuration on performance. All these demands would be realize by applying an advanced technology and performance tools, intelligent software of CAD-CAM systems and a higher management [1].

Milling is a metal cutting process, in which the cutting tool intermittently enters and leaves the workpiece, unlike turning, where the tool is always in contact. In both milling and turning chatter is an important instability that limits metal removal rate. Tlusty and Tobias (1965) developed frequency-domain methods for stability analysis of continuous cutting. These methods have been used widely to determine exact stability boundaries for turning, and approximate stability boundaries for milling.

Significant improvements were made by Minis and Yanushevsky (1993) and Altintas and Budak (1995). Also, Altintas and Budak (1995) provide a complete frequency-domain algorithm for end-milling that accounts for x- and y-deflection of the tool, and uses a truncated Fourier series to approximate the periodic entry and exit of the tool from the cut. With a single Fourier series term, this method provides accurate stability predictions except for cuts with very low radial immersion, where a small fraction of time is spent in the cut. Davies (2000) analyzed the limiting case of extremely low radial immersion milling. Bayly (2001) extended the approach of Davies and co-workers by the use of

time finite element analysis (TFEA). The research had continued by Landers and Ulsoy (2002) with study of dynamic milling process at chatter with linear and non-linear force process.
This paper has presented the analyses of milling process for a traditional precision milling machine with a side milling cutter with inserts, by a dynamic installation which is able to acquisition on three directions of cutting forces and vibrations.

2. DYNAMIC MACHINING SYSTEM

The dynamic machining system (DMS) [2,3] has represented by the interaction between elastic structure (SE) of machine tool and cutting process (PA). The cutting force, which occurred during cutting process, is dependent by a certain factors as: thickness cut, width of cut, physics-mechanics properties of workpiece, geometry of shaped edges tool, etc. The most influence of system is getting by thickness cut a=a(t), that due to the dynamic displacement of tool-y(t):

$$x_i = x_i(t) = F_o(t) \qquad x_e = x_e(t) = y(t) \tag{1}$$

$$y = y(t) = a_o - a\ (t) = \Delta a \tag{2}$$

, where a_o is nominal thickness cut.

$$F \cong F_o + \left(\frac{dF}{da}\right)_{a=a_o} (a - a_o) \tag{3}$$

$$\Delta F = \left(\frac{dF}{da}\right)_{a=a_o} \Delta a \tag{4}$$

, where ΔF is dynamic variation of cutting force. In final, the cutting force becames:

$$F = F_o - \left(\frac{dF}{da}\right)_{a=a_o} y \tag{5}$$

For traditional machine tools (see Fig.1), the DMS is composed by the following blocks: *SE*-elastic system of machine tool, *PA*-cutting process, *SA*- dynamic acting system for kinematics chains of machine tools, and *PF*- dynamic system of friction process.

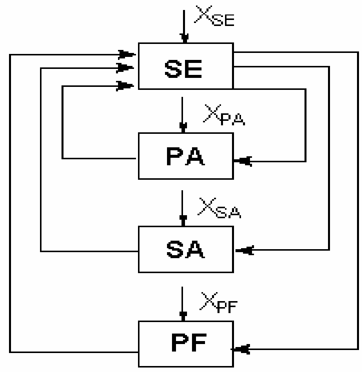


Figure 1: The block diagram of dynamic machining system

At machine tools with adaptive control or CNC, the DMS [2,3] is more complex by adding the reference block-R and transducers-T_R for deformation measurement (Fig.2). The correlation between reference value-g_r and thickness cut-g_0 has get by the adaptive system has realized from an electric motor-M, commanded by a controller-C, which acting about acting system and cutter. The value-ΔL is the deviation of dimensional workpiece about nominal value and block-R is described the dependence between reference values g_0 and F_0.

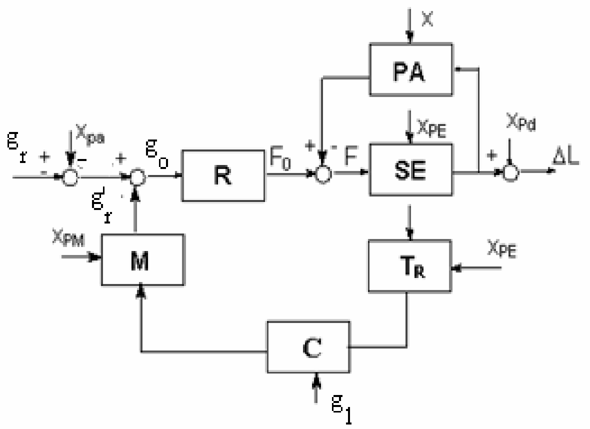


Figure 2. The block diagram of dynamic machining system with adaptive control.

The solutions for suppressing vibrations could be: increase static stiffness, reduce cutting forces, and enhanced dynamic stiffness. All these can be obtained by dynamic identification method, which means determining the structure machine model, the eigenfrequencies with corresponding mode shape, dynamic equivalence parameters: (m)-equivalent mass, (c)-equivalent dumping constant, (k)-equivalent stiffness, and reduced difference between analytical and experimental system model.

3. ANALYSIS OF DYNAMIC MILLING PROCESS

The dynamic installation [2] has used for study of milling cutting process is composed from: milling machine tools (FUS 22-modified), side-milling cutter with inserts, dynamometer, bridge circuit with strain gages, accelerometer KD 35, operational amplifier, A/D-board (electronic interface PCI 12000) and PC computer. The milling machine is a classical precision milling machine type FUS22-modified, by change the motor of 3000rev/min (it was 1500rev/min) in two shifts-I=1500 rpm, II=3000rpm.
The modeling of milling process [2,5-8] has been done by using a side milling cutter with three cutting edges and eight positive triangle inserts, type TCMT 16T308T N7010. The forces are described as harmonic functions and dynamic equation of milling cutter is written:

$$\{F\}e^{i\omega_c t} = \frac{1}{2}\bar{t}\cdot K_t\left[1-e^{-i\omega_c T}\right][B_0][\Gamma(i\omega_c)]\{F\}e^{i\omega_c t} \tag{6}$$

, where: *$[B_0]$*-directional forces components matrix of average component of Fourier series expansion, K_t-coefficient of cutting force, *$[\Gamma(i\omega_c)]$*-matrix of transfer function in tool-workpiece contacted zone. The eigenvalues of characteristic equation is defined as:

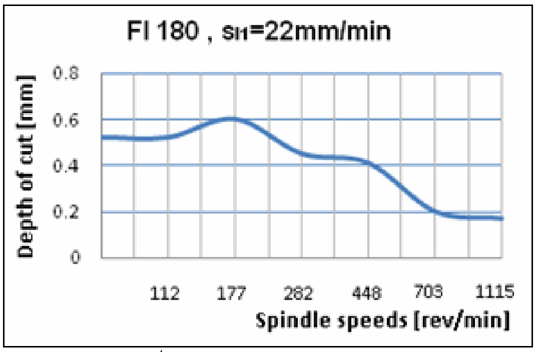
$$\Pi = -\frac{N_z}{4\pi}\bar{t}\cdot K_t\left(1-e^{-i\omega_c T}\right) \tag{7}$$

The critical depth cut at resonance frequency can be written:

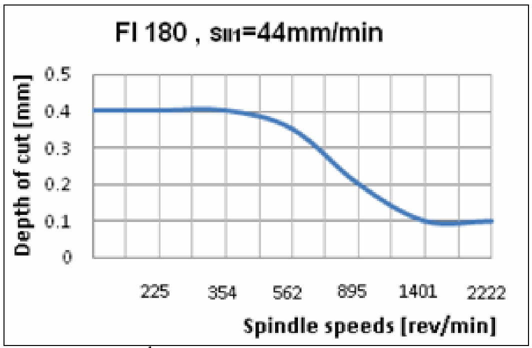
$$\bar{t}_{cr} = -\frac{2\pi\Pi_R}{N_z K_t}\left(1+\frac{\sin\omega_c T}{1-\cos\omega_c T}\right) \tag{8}$$

, where: Π_R-is real part of eigenvalue, N_z-number of inserts, $\omega_c T$- is delay phase between vibrations at successive tooth period.
The dynamic tests had done by variation depth of cut until occurring chatter [9], with keeping of feed speed constant. The tests had executed by up-milling process, with the feed speed-s_{I1} = 22mm/min for first shift motor and s_{II1} = 44mm/min for second shift motor. The cutter-FI 180 is a side-milling cutter

with three cutters, diameter-Ø180mm and eight interchangeable triangles carbide inserts type TCMT 16T308T N7010, with angle $\alpha = +6^0$ and pitch angle $\delta = 45^0$.
The results of tests have presented in Fig.3, where A-represents the milling machine's motor at first shift and B-represents the motor at second shift.



A.-1st shift of motor



B.-2nd shift of motor

Figure 3. Stability diagram of milling process for side-milling cutter FI 180.

4. CONCLUSIONS

The paper has presented some aspects about analyses of dynamic stability of milling process by used a dynamic installation of acquisition of cutting forces and vibrations. The dynamic machining system represents an important factor in analysis of behavior of milling machine and founds the elements which determined the stability of process.
This is possible by calculus of eigenfrequencies of milling machine and critical depth of cut, which due to determines the stability diagram of milling process, with direct data about stability of process and those influence's factors of milling machining process.

5. REFERENCES

[1] Pop, P.A., Bejinaru-Mihoc, G.: Proceedings Used For Enhancing Machining Process, 11th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology" Proceedings of TMT 2007, Hammamet, Tunisia, 5-9, September 2007, Vol. XXVIII(62), pp. 191-194, ISBN 978-9958-617-34-8, 2007.,

[2] Pop, P.A.: Influence of Equivalence Dynamic Parameters Variation about Behavior of Structure Milling Machine Tools, ASME IDETC/CIE Conference 4-7 sept.2007, Las Vegas, Nevada, USA, 21st Biennial Conference on Mechanical Vibration and Noise (VIB), Proceeding of DETC2007, Paper No-DETC2007-34050, pp.1-10, 2007.,

[3] Chiriacescu, C.S.: Stability in Dynamic of Metal Cutting, Elsevier Science Ltd, New York, Amsterdam, 1990.,

[4] Altintas, Y.: Manufacturing Automation: Metal Cutting Mechanics, Machine Tool Vibration and CNC Design, Cambridge University Press, ISBN 0-521-65973-6, pp. 33-46, 2000.,

[5] Altintas, Y.: Modeling Approaches and Software for Predicting Performance of Milling Operation at MAL-UBC, JMTS Review Paper Altintas.pdf, pp. 1-15, 2000.,

[6] Altintas, Y., Budak, E.: Analytical Prediction of Stability Lobes in Milling, Annals of the CIRP, pp. 357-362, 1995.,

[7] Landers, R.G., Ulsoy, A.G.: Chatter Analysis of Machining Systems with Nonlinear Force Process, ASME International Mechanical Engineering Congress and Exposition Atlanta 17 nov.1996, DCS., 58, pp. 183-190, 1996.,

[8] Landers, R.G.: Process Analysis and Control of Machining Operation, Washington University 2002, University of Missouri at Rolla, pp. 1-44, 2002.,

[9] ***: General Motors/Delphi Vibration Standard for Purchase of New and Rebuilt Machinery and Equipment, V1.Oa-1999, GM Vib.pdf, 2001.