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PROCEEDINGS USED FOR ENHANCING MACHINING PROCESS

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ABSTRACT
This paper has presented certain proceedings used for improving machining process, in special at milling machine tools. These methods are contained theoretical and practical solutions for suppressing the vibrations level and magnitude of cutting forces which due to enhancing cutting process of machine tools. For study of vibrations level and its dumping can be used different control techniques as: active and passive damping of vibrations, adaptive control techniques and some practical methods by changed the geometrical parameters of milling cutter. The dynamic installation used for control of milling process has measured the vibrations and cutting forces in milling process, also were monitoring the spindle speeds and noise.
Keywords: enhancing, optimization, side milling cutter.

1. INTRODUCTION
The mechanical cutting by milling process has known a great development in last years, being used in more that 60% by all machining process volume. These are happened as a widely using of machine tools with high machining speeds and performance tools with inserts, high accuracy and intelligent software, which due at workpieces with roughness of R_a=0.4-0.6μm. All of these are enable to alter the grinding process with precision milling which due at rise productivity and low costs.
For manufacturers of machine tools occurring vibrations is a permanent impediment between the qualities of final workpiece and productivity, trying to find the solutions for suppressing the vibrations during the cutting process. The main sources of vibrations for machine tools [1] are: gearings, ball bearings, electrical motors, self-vibrations, wear process and lubrication type, etc. For these are some solutions which improve the machining process and avoid the vibrations such as:

- the elements of elastically structure of machine tools being in rotation motion (main spindle, flanges, etc) must to be dynamic balanced;
- the execution and mounting the items of machine had been more accuracy;
- a correct mounting of machine on foundation of workshop;
- using methods for grown the dynamic stiffness of elastically structure of machine by improve static stiffness and dumping coefficients, and a good orientation for them eigenvalues direction which due to rising the dynamic stability of machining system.

The methods used for improving dynamic stiffness of machine tools are: enhancing the dumping of machine by using dumpers, vibrations absorbers, anti-vibration isolation of machine, and a certain constructive solutions. The enhancing dynamic stability of machining process can be obtained from: optimizations of main spindles, using the cutters with high stability at vibrations, finding direction of eigenvalues with greater elastic constant located near probably direction of cutting force, etc.

2. METHODS OF IMPROVING MACHINIG PROCESS

Ones of important method has used for enhancing dynamic performance of machine tools and rise productivity is optimization of main spindle [5]. A proceeding used for optimization of main spindle in steeped diameters [6] with multiple optimization objectives is presented in fig.1.

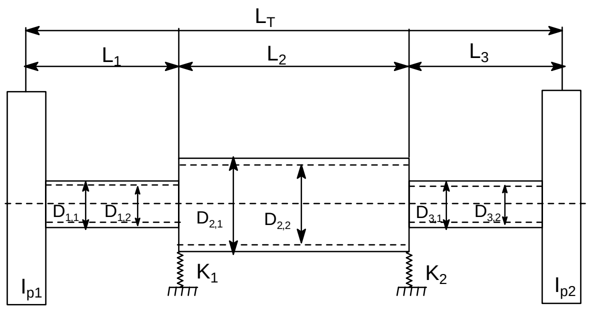

Figure 1. The calculus diagram of main spindle.

The main spindle is supported on two elastic rests, its total mass-m_T, torsion static compliance-f_{st} and bending static compliance-f_{sb},, can be determined with formulas:

$$m_T = \frac{\pi\alpha}{4}\left[\left(D_{1,1}^2 - D_{1,2}^2\right)L_1 + \left(D_{2,1}^2 - D_{2,2}^2\right)L_2 + \left(D_{3,1}^2 - D_{3,2}^2\right)L_3\right] \quad (1)$$

$$f_{st} = \frac{32L_1}{\pi G\left(D_{1,1}^4 - D_{1,2}^4\right)} + \frac{32L_2}{\pi G\left(D_{2,1}^4 - D_{2,2}^4\right)} + \frac{32L_3}{\pi G\left(D_{3,1}^4 - D_{3,2}^4\right)} \quad (2)$$

$$f_{sb} = \frac{64L_1^3}{3\pi E\left(D_{1,1}^4 - D_{1,2}^4\right)} + \frac{64L_1^2 L_2}{3\pi E\left(D_{2,1}^4 - D_{2,2}^4\right)} + \frac{1}{K_1}\left[\left(\frac{L_1}{L_2}\right)^2 + 1\right]^2 + \frac{1}{K_2}\left(\frac{L_1}{L_2}\right)^2 \quad (3)$$

Where: $D_{i,1}$ and $D_{i,2}$ (i=1,2,3) are external diameters, respective inner diameters of spindle, the diameters D_1 and D_2 being variable from design for optimization. The multiple objectives are minimization of total mass-m_T, and static compliance-f_s (f_{sb} or f_{st}) which are transformed in one objective by introducing the ponderable factor –θ, being mentioned in equation:

$$\psi_0 = \theta\frac{m_T}{m_{T\max}} + (1-\theta)\frac{f_s}{f_{s\max}} \quad (4)$$

The system constrains are:

$$\begin{aligned}\psi_i &= D_{i,1} - D_{\max} \le 0\\ \psi_{i+3} &= D_{\min} - D_{i,2} \le 0\\ \psi_{i+6} &= 2t_{\min} - \left(D_{i,1} - D_{i,2}\right) \le 0, \quad i = 1,2,3\end{aligned} \quad (5)$$

The Lagrange function-Φ is formulated by using multiples-v_i (i=1,2,…9):

$$\Phi = \psi_0 + \sum_{j=1}^{9} v_j \psi_j \quad (6)$$

By using Kuhn-Tucker constrains [6] for optimization are obtain 512 possible combinations for constrains and 9 inequalities for multiples-v_j.

A widely method has used for improving dynamic stiffness of elastically structure of machine tools [5] is using dumpers. There are a lot of constructive solutions of dumpers such as: dumpers with dry friction, hydraulic dampers, dupers with viscous friction, dumpers with auxiliary mass, self-tuning dumpers, etc. These dumpers are located on elastic structure elements much near from workpiece or cutter, without influences of static stiffness of structure. In another situation are used absorbers which are more types as: dynamic absorbers with variable stiffness, absorbers with eddy-current damping, dynamic absorbers for gearing, dynamic absorbers which produced anti-resonance, etc. This paper has presented a dynamic viscous-elastic damper [3] used for suppressing vibration of machine tools, can be attached at tool-holder of machine. The dynamic properties of viscous-elastic material (fig.2) depended of elastically modulus-E and lost factor-δ, being in general depending by pre-load force and frequency. The complex elasticity modulus of viscous-elastic material is got by relation:

$$E^* = E(1 + j\delta) \tag{7}$$

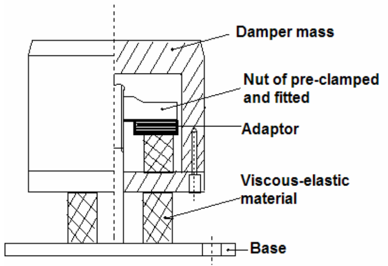

Figure 2. Dynamic viscous-elastic dumper.

For an ideal model, where primary system is a system with one grade of freedom, and its dumping is negligible versus its dynamic dumper, the objective function which is got to be minimized is given by transmissibility-T:

$$T = \frac{n^2 - \Omega^2\alpha + jn^2\delta}{\mu\Omega^4\alpha - \Omega^2\left(n^2 + \alpha\right) + n^2 + j\left[n^2\delta\left(1 - \Omega^2\right)\right]} \tag{8}$$

Where: $n=\omega/\omega_o$-is fitted factor, $\Omega= \omega/\omega_a$-is frequency factor, $\omega_o^2 = k/(M_1 + M_2)$ -is reference frequency, M_1-is primary mass, M_2-is dumper mass, k-stiffness system, $\omega_a^2 = k_e E_a / M_2$ -is resonance frequency, $\mu=M_1/(M_1+M_2)$-is mass factor, $\alpha=E_a/E$-is elastically modulus factor.

For optimization is chosen two different viscous-elastic materials by application of Den Hartog [3] optimization principle. The chosen of viscous-elastic material, its elastic modulus and lost factor is done at certain load-temperature conditions. The mass factor is estimated for an optimal dumping at a load-temperature fixed. For a variation of reference frequency, the adjustable load is done by using:

$$E_a = n^2\omega_o^2 \frac{M_2}{k_e} \tag{9}$$

At milling process with high speed machining is required to use advanced toolholder, as hydraulic chucks [2] that assured a good center of cutter minimized vibrations at main spindle of machine tools. There are used shrink-fit toolholding, where holder is heated using induction heating, air, or some other method. These methods had improved machining accuracy and workpiece surface finishes while helping to extend tool life.

For study the behavior of milling machine tools has been used a dynamic installation [5] composed from: milling machine tools (FUS 22-modified), side milling cutter, dynamometer, bridge circuit with strain gages (Switch & Balance Unit SB-10, Strain Indicator P-3500, "Instrument Division Raleigh", North Carolina), accelerometer KD 35 (Metra Mess), operational amplifier, A/D-board (electronic interface PCI 12000) and PC computer. This dynamic installation has monitorized the milling process on three axes of machine by measuring vibrations, cutting forces using Matlab R14 Program for acquisition data and interpretation of tests results. As cutters had been used side milling cutters with three cutting edges and eight positive triangle inserts, type TCMT 16T308T N7010, which had designed by authors. The dynamic tests had been consisted in rising gradually depth of cut until occurred chatter, using the same feed for all revolutions of machine. First test has done by using a side milling FI 180, with outer diameter 180 mm and straight teeth, which is followed by second test by using a side milling FI 160 with outer diameter 160mm and zigzag teeth. By these geometrical changes of side milling cutters the cutting parameters process had improving by suppressing vibration, reducing cutting force, and rise dynamic stability of milling process, for example at spindle speed n=1115rev/min and depth of cut a=0.1mm the main cutting force (F_y-force on *Y*-axe) has reduced from 3220daN at 1465daN. The tests were continued with cutters FI 180 and FI 160 with differential pitch where force had reduced at Fy=1450daN, respectively Fy=972daN by using same cutting conditions (fig.3), and stability process has been improved from 0.1mm at 0.2mm by suppressing vibrations.

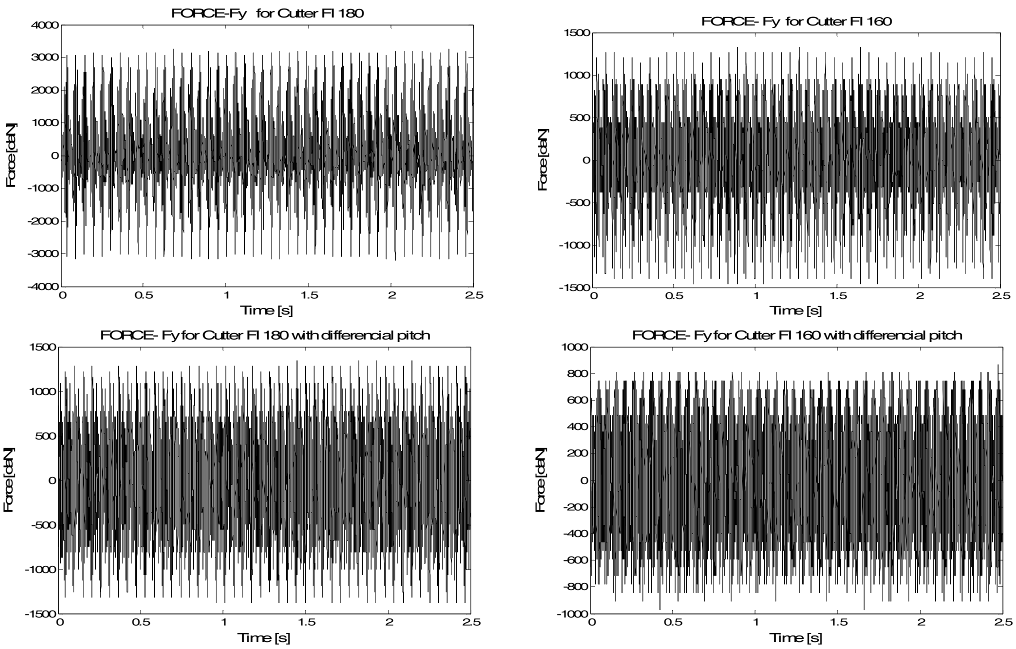

Figure 3. Waveform diagrams of cutting force-F_y.

3. CONCLUSIONS

This paper has presented some solutions for improving cutting process by using optimization of main spindles, dynamic dumpers and absorbers, advanced toolholders and by chancing the geometrical parameters of cutters. For that the authors had used a dynamic installation and four side milling cutters with inserts by chancing geometrical parameters of cutter as: outside diameter, position of inserts and pitch of teeth, which due to enhancing the milling machining process.

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