Dynamic Characteristics of Plane Milling, Obtained on the Basis of Numerical Simulation

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***Abstract*— The article shows the technique of frequency analysis of flat surface milling with uneven allowance. The results of finite element modeling of the cutting process are presented. A frequency analysis of the dynamics of the cutting forces based on the calculation data is carried out.**

***Key words*— flat milling; uneven; allowance; vibrations; frequency; cutting force; numerical**

I. Introduction

The dynamics of changing of cutting forces during milling has a complex oscillatory character due to the periodic change in the thickness of the removal allowance, the geometry of the tool (the shape of the cutting edge, the number of teeth and other parameters), the random and predictable change in the geometry of the machined surface (undulation, roughness). The use of intensive cutting modes for roughing and semi-finished milling is mainly restrained by the loss of the dynamic stability of the technological system.

II. Statement of the Problem

A. Finite element simulation of flat milling

The problem of modeling the process of chip formation was solved in a three-dimensional formulation with the help of a finite-element packet [1].

Fig. 1 shows the geometric model of the billet (flat) and four-edged milling cutter. Stages of modeling were standard: the adjustment of the solver, the construction of geometry, the generation of the grid, the solution [2, 3].

The peculiarity of calculations for problems with destruction is the restructuring of the grid on each step and increased resource intensity as a consequence.

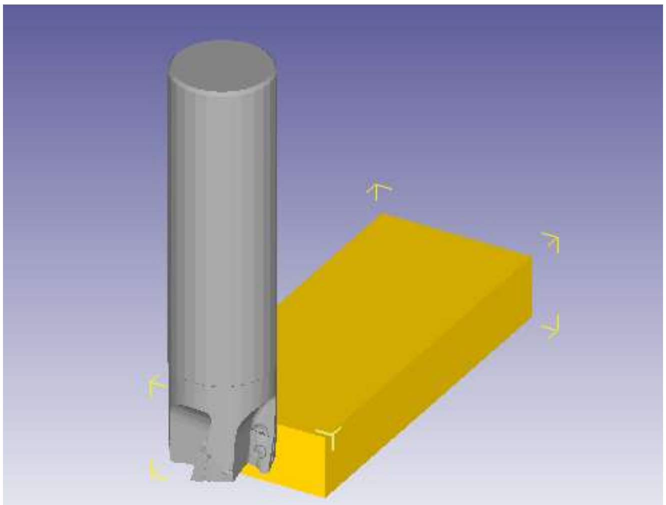

Fig. 1. Tool and workpiece models

We obtained graphs of the periodic variation of the cutting force components shown in Fig. 2–3 as a result of the simulation.

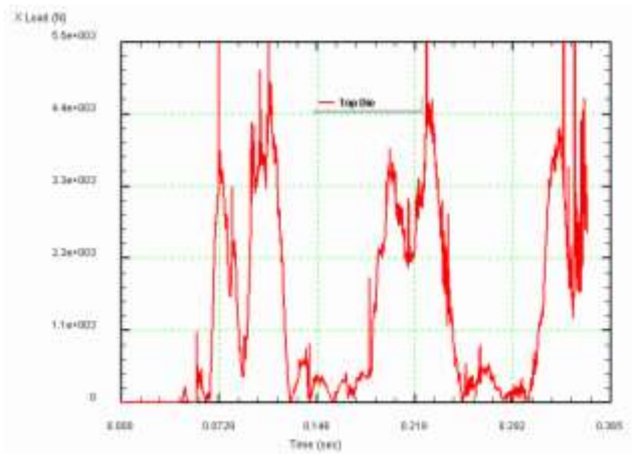

Fig. 2. Component of cutting force Px

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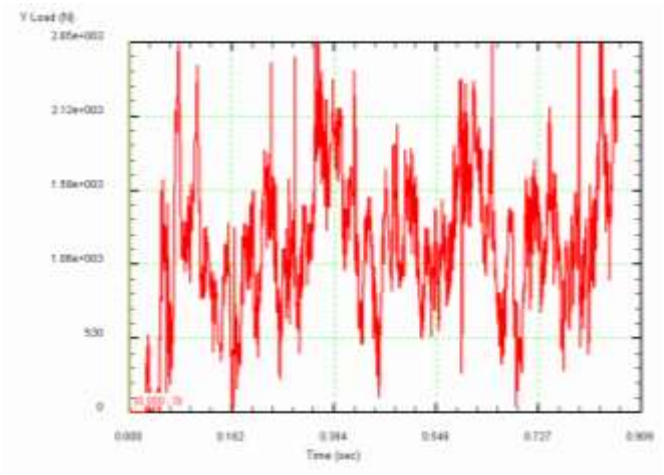

Fig. 3. Component of cutting force Py

The graphs of Fig. 2 and 3 show the periodic nature of the change in the cutting force due to the cutting input and output of the cutting teeth of the milling cutter, the removal of chips and the processes of elastic and plastic deformation in the cutting zone.

The problem with a non-constant allowance was solved in order to obtain the dynamics of the cutting forces caused by the geometric inaccuracy of the surface-the undulation (see Fig. 4).

Fig. 5–6 show the results of the solution of the problem taking into account the changing geometry of the workpiece – the undulation of the surface. The results of simulation of flat milling are presented in the form of graphs of changes in the components of cutting forces. For clarity, the workpiece model was presented as a surface with a periodic relief of a sinusoidal shape.

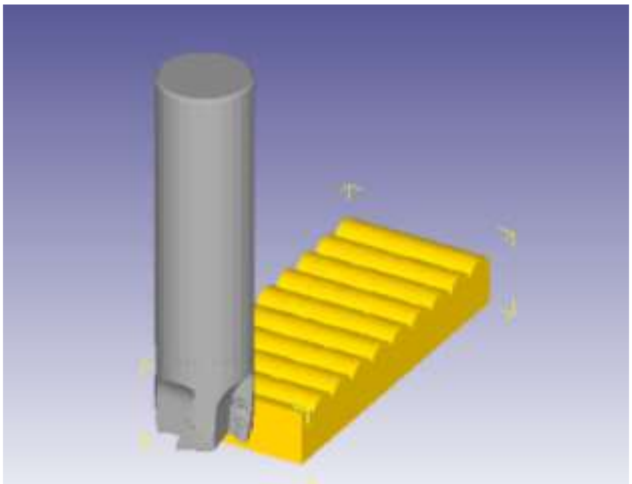

Fig. 4. The model of the tool and workpiece, taking into account the unevenness of the allowance (the surface is shown on an expanded scale)

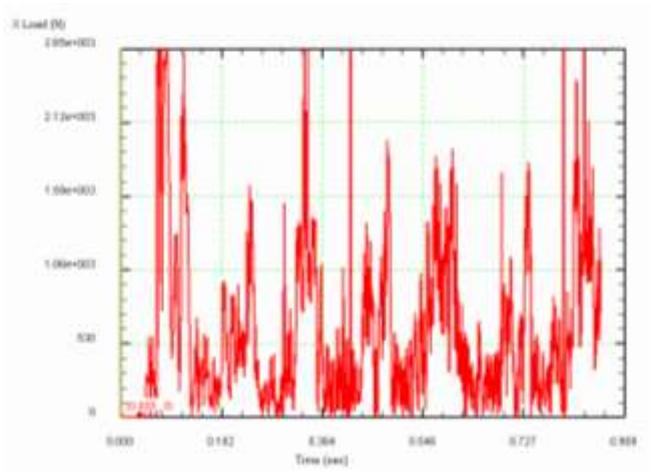

Fig. 5. Component of cutting force Px for milling a wavy surface

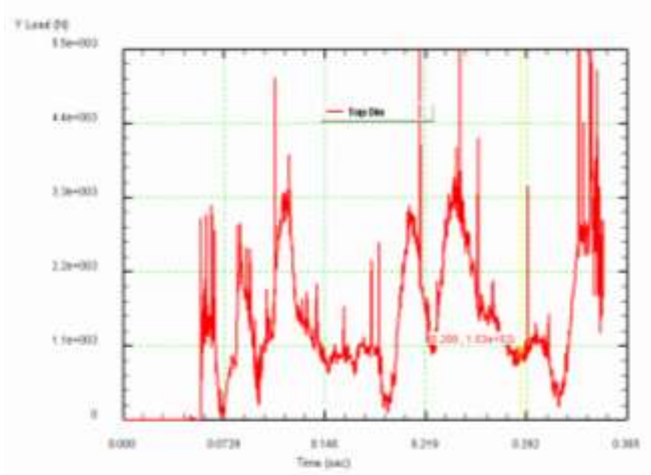

Fig. 6. Component of cutting force Py for milling a wavy surface

B. Determination of the amplitude and frequency spectrum of a periodic process..

To obtain the frequency characteristics, a fast Fourier transform of the received data in the Matlab packet was made using the FFT-function. Fig. 7-8 shows the spectrum of frequencies for the case of milling a plane surface when the oscillation is caused by the input-output of the cutter teeth from the cutting zone, variable allowance, chip exit.

For example, Fig. 7, 8 shows the graph of the spectral density of forces Fx and Fy for flat milling at a speed of 470 rpm and feed 0,3 mm / tooth.

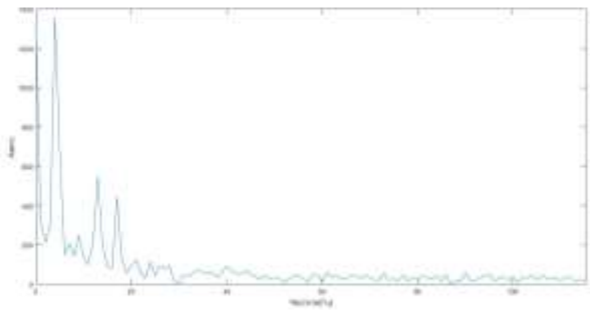

Fig. 7. Spectrum of amplitudes and frequencies Fx for plane milling

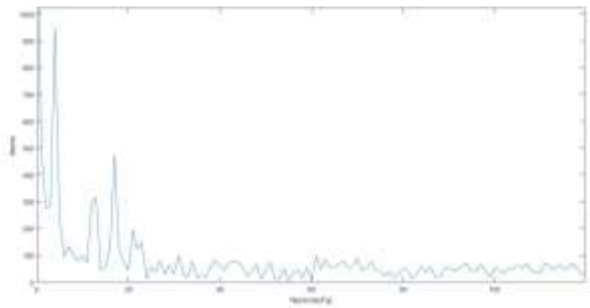

Fig. 8. Spectrum of amplitudes and frequencies Fy for plane milling

For milling a wavy workpiece, the expansion of the component of cutting forces in a row and the amplitude-frequency spectrum are shown in Fig. 9, 10.

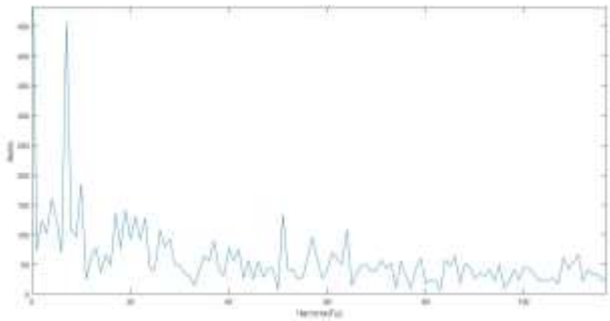

Fig. 9. The spectrum of the amplitudes and frequencies of the force Fx for milling a wavy surface Fx

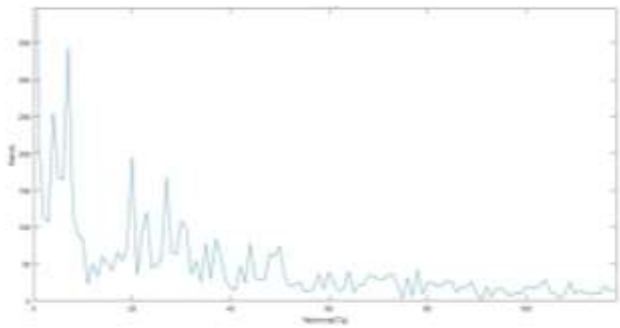

Fig. 10. The spectrum of the amplitudes and frequencies of the force Fy for milling a wavy surface

The carried out amplitude-frequency analysis made it possible to determine the expansion coefficients in the Fourier series of cutting forces obtained in a numerical experiment. Analytical functions that describe the components of the cutting force for further optimization of the technological process with the help of the found coefficients can be obtained. For example, at a cutting speed of 470 r/m the cutting forces can be approximated by three members of the Fourier series which characteristics are given in Table 1.

TABLE 1 AMPLITUDE-FREQUENCY CHARACTERISTICS

Surface	Force component	Amplitude A, N			Frequencies *f*, Hz		
		A1	*A2*	*A3*	*f1*	*f2*	*f3*
Plane surface	Fx	2708	1094	882	4	13	17
	Fy	1900	948	630	4	17	13
Wavy surface	Fx	914	370	318	7	10	4
	Fy	508	706	390	4	7	20

III. RESULTS AND CONCLUSIONS

The dynamic picture of the change in the force parameters in the cutting zone is obtained and investigated when the tool is cut in and out of the cutting zone and the periodic nature of the change in cutting forces during milling is determined.

The amplitude and frequency spectrum of the component cutting forces varying periodically in connection with the nature of the cutting process during milling is obtained.

The results of the work allow us to determine the effective technological regimes from the point of view of the occurrence of self-oscillating processes in the "workpiece - tool" system and to determine the qualitative relationship between the technology and the quality of the product.

REFERENCES

[1] Grinek A.V., Rubanov V.G., Kalatozishvili I.V., Mikhailov V.V. Investigation of the effect of the cutting speed on the temperature-strength state in the treatment zone by the numerical simulation method. Vestnik Irkutskogo gosudarstvennogo tekhnicheskogo universiteta [Bulletin of the Irkutsk State Technical University]. 2016. No. 8. Pp. 10-19. (In Russian).

[2] Gok K,, Gok A., Bilgin M.B. Finite Element Modeling as Three Dimensional of Effect of Cutting Speed in Turning Process. Journal of Engineering and Fundamentals. 2014. No. 1(1). Pp. 11–22.

[3] Zhai Y.S., Wang Y., Yan F.G., Wang B. Three-Dimensional Finite Element Analysis in Plunge Milling for Stainless Steel. Materials Science Forum. 2014. Vol. 800-801. Pp. 348-352.

[4] Abboud E., Shi B., Attia H., Thomson V., Mebrahtu Y. Finite element-based modeling of machining-induced residual stresses in Ti-6Al-4V under finish turning conditions. Procedia CIRP. 2013.Vol.8. Pp. 63–66.

[5] Subramanian M., Sakthivel M., Sooryaprakash K., Sudhakaran R. Optimization of end mill tool geometry parameters for Al7075-T6 machining operations based on vibration amplitude by response surface methodology. 2013. Meas J Int Meas Confed, 46:40054022. https://doi.org/10.1016/j.measurement.2013.08.015