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INFLUENCE OF THE MACHINE ELASTIC SYSTEM AND THE TOOL WEAR OVER THE DEVIATION AT CONTOUR PROCESSING OF STONES

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ABSTRACT. A fragment of a complex bas-relief is presented and the types of its shape, waviness and roughness deviations are shown.
The distribution of dimensions of the slime chip particle at stone cutting with sharp and blunt cutter and the roughness obtained at these cases are presented.
A stand for spectral analysis is processed. Results of superposition of the spectrum of marble cutting with a sharp and blunt tool and its natural frequencies along the axis Z are presented.
A dynamic analysis of the machine elastic system closed by the cutting process of marble is carried out (amplitude and phase frequency characteristics).
The oscillations of the tool point at turning of marble with rendering an account of the tool sharpness are shown.

ВЛИЯНИЕ НА ЕЛАСТИЧНАТА СИСТЕМА НА МАШИНАТА И ИЗНОСВАНЕТО НА ИНСТРУМЕНТА ВЪРХУ ОТКЛОНЕНИЯТА ОТ ФОРМА НА ПОВЪРХНОСТТА ПРИ КОНТУРНА ОБРАБОТКА НА СКАЛНИ МАТЕРИАЛИ

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РЕЗЮМЕ. Представен е фрагмент от съставен барелеф и са разгледани видовете отклонения от форма, вълнообразност и грапавост.
Третира се разпределението на размерите начастиците на стружката при рязане на скални материали с остър и тъп инструмент, и получаваната при тези случаи грапавост.
Разгледан е стенд за провеждане на спектрален анализ. Представени са резултатите от налагането на спектръра напроцеса на рязане н мрамор с остър и тъп инструмент, и неговете собствени честоти по ос Z. Направен е динамичен анализ на еластичната система на машината, затворена от процес на рязане на мрамор (амплитудно-фазови честотни характеристики).
Показани са колебанията на върха на инструмента при струговане на мрамор, с отчитане на остротата на инструмента.

The volumetric images with complex profile on the surfaces of hard materials, including the bas-reliefs are wide used as architectural details, facing elements and at the manufacturing of interior articles as well. The use of different materials (several types of marble, for example) in a bas-relief, allows the article artistic expressiveness to be increased. At that, it has to be taken into account that the materials combined could considerably differ in their physical and mechanical properties and consequently, in degree of workability. As a rule, such composite bas-reliefs have fragments with complex front surfaces, constrained by curvilinear three-dimensional limits.
At the assembly, it is important the joint of these fragments to be provided, so the requirements to the shape accuracy of the fragments and the quality of their surfaces are of substantial significance.

Fig. 1 shows a fragment of composite bas-relief of general type (Миков И.Н., Мезенцева И.Л., 2008). The base of such a bas-relief is a plain. The lateral surface represents a sector of a straight cylinder, which generatix is perpendicular to the plain *xOy.* The projection of the cylinder on the plain *xOy* has the profile (contour) of the bas-relief fragment on this co-ordinate plain. The front surface of the bas-relief is the bearer of the artistic image. In the general case, the bas-relief front surface is constrained by a three-dimensional curve. At the bas-relief assembly, the joint surfaces are the base and the lateral surface. At that, of great importance is the lateral surface, which connects to the analogous surfaces of the adjoining bas-relief fragments. The difficulty consists in the connection of the three-dimensional curve, constraining the front surface of the bas-relief fragment, to the analogous curves of the adjoining fragments.

The types of deviations from shape, waviness and roughness, characterizing the bas-relief quality, are presented in fig. 2.
Nominal front surface, real front surface, respectively upper and lower positions of the points of the real front surface.
Deviation of the front surface of the bas-relief fragment is the distance Δ between the points of the real and the nominal front surface of the bas-relief fragment, measured along the normal to the nominal surface (fig. 3), (Радкевич Я.М., Схиртладзе А.Г., Лактионов Б.И.). The tolerance *T* of the front surface deviation consists of the sum of the tolerances T_H and T_L determining the location of the points of the real front surface,

respectively disposed upper and lower of these of the nominal front surface. If the values of T_H and T_L are determined to be constant for the whole front surface, the latter would be locked between two plains, which are equidistant to the nominal (fig. 3). The upper and the lower surfaces determine respectively the upper and the lower limits of tolerance. In case, when the plain tangent to the nominal front surface is insignificantly inclined to the plain *xOy*, it is possible the deviation to be measured by the difference of the z-coordinate of the points of the real and nominal front surfaces. But the error at such a measurement increases at growth of the angle of inclination of the tangent plain. The cutting of marble is at the expense of breaking down of small particles of the material.

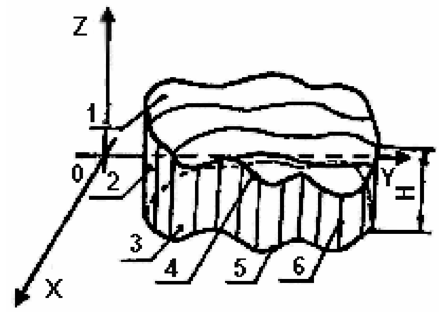

Fig. 1. Fragment of a composite bas-relief: 1 - front surface; 2 - latteralsurface; 3 - basis; 4 - line constraining the front surface; 5 - profile on the plain xOy (line constraining the basis); 6 -generatix of the latteral surface.

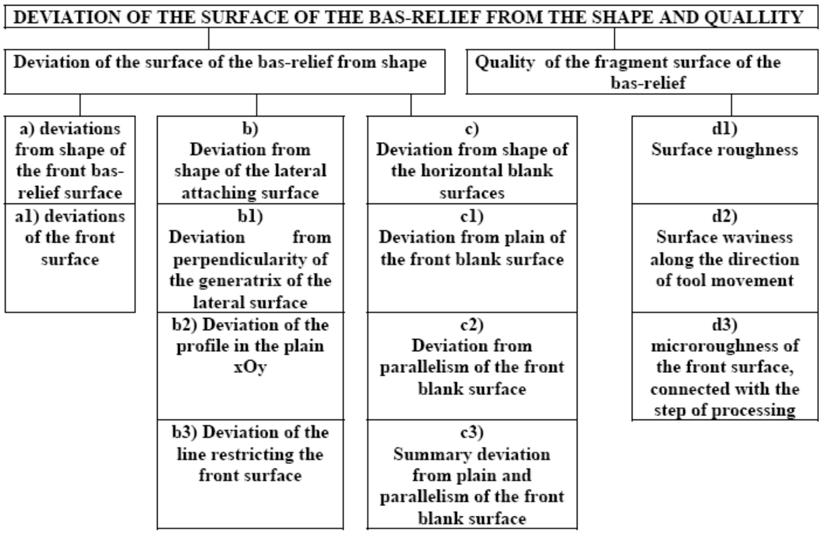

Fig. 2. Types of deviations from shape, waviness and roughnes of the bas-relief sfragment.

At research of the particles obtained at turning with sharp and blunt cutter, a conclusion could be made about the connection of their size and the tool wear. The sharp cutter provides slime chip (cracked) with particles 1-3 μm and the blunt – with 6-12μm. The quantity of the larger fraction in the whole mass of chips is bigger at operation with blunt cutter. The distribution of the size of the particles, formed in the cutting process with sharp and blunt tool is shown in fig. 4.

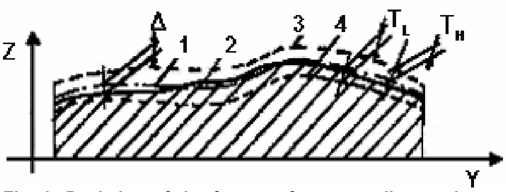

Fig. 3. Deviation of the front surface according to the equidistant: 1 - nominal front surface; 2 - real face surface; 3 and 4 - respectively the upper and lower positions of the points of the real front surface.

The cutter wear brings to growth of the cutting force. The oscillating processes in this case are more intensive, which causes increase in roughness and deviation from the specified profile. The data obtained at research in the slam chip and the processed surface, according to their connection with the wear is presented in Table 1.

The statistics of the roughness of marble blank surfaces, obtained after turning with a sharp tool, tool with off-taken edges and blunt tool, at t=1mm, n= 400min^{-1}, s= 0,12 m/min and material of the tool - hard alloy plate - are presented in fig. 5, Table 2 and fig. 6.

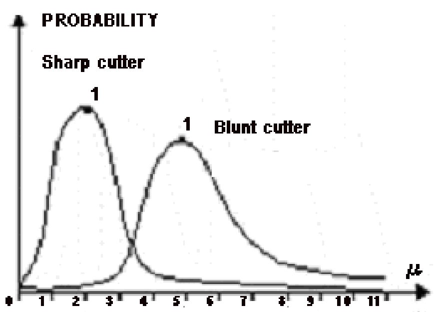

Fig. 4. Distribution of the size of the particles for a sharp and blunt tool.

Fig. 6 shows examples of profilogrammes of marble detail after turning with hard alloy tool, according to the fig. 5. It could be seen that the wear influences negatively the quality of the surface, increasing its roughness.

The cutting process of brittle materials, for example cutting of marble (fig.7) is accompanied by the variable and steady components of the cutting force (Козочкин М. П., 2005). The reason for the origin of the variable component of the cutting force in this case is the fact that, as it has been already mentioned, the cutting of brittle materials (for example marble) is at the expense of breaking down of the material small particles.

Table 1. Chip and roughness of the surface.

	Dimond-abrasive processing		Sharp cutter		Blunt cutter	
	Marble	Granite	Marble	Granite	Marble	Granite
Dimensions and shape of the chip, mm	-	-	1-3	6-12	4-6	6-12
Roughness R_a, μm	2,91 average value	3,71 average value	1-6	No data	> 8	>4

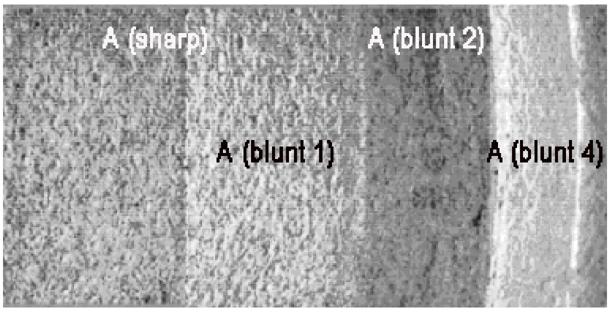

Fig. 5. Surface of a marble blank after processing with a sharp tool, tool with off-taken edges and blunt tool.

Table 2. Results from measuring of the surface.

R_a, μm	Plate condition
$R_{a\ cp}$ = 5,82 μm	Sharp A
$R_{a\ cp}$ = 6,75 μm	With off-taken edges A1
$R_{a\ cp}$ = 6,78 μm	With off-taken edges A2
> 10	Worn A3

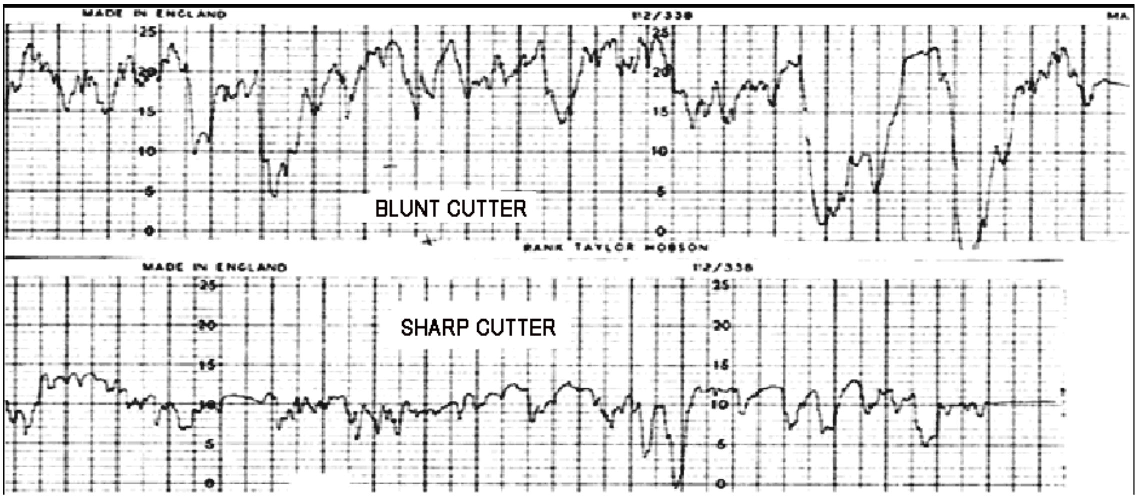

Fig. 6. Examples of profillogrammes of marble processed surfaces.

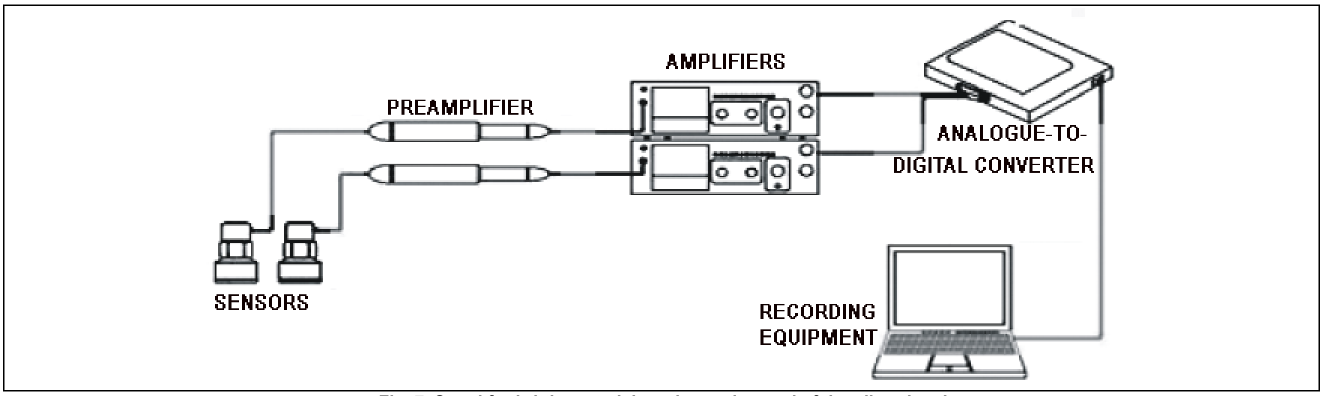

Fig. 7. Stand for brittle material turning and record of the vibrosignal.

An example of the acceleration spectrum, registered on the tool holder at the marble turning is presented in fig. 8. Fig. 9 shows an example of the spectrum, obtained in full accordance with the conditions of fig. 8 but at turning with blunt tool. The comparison shows that the wear has not only changed the amplitudes of different frequencies, but has altered the ratio as well: the amplitudes of high frequencies have decreased, while those of the low frequencies have increased.

While for a sharp tool the ratio of amplitude of frequency about *10Hz* to the amplitude of frequency close to 10 *KHz* is about 0,12, for a blunt tool the ratio is 0,94, i. e. has increased almost 8 times. The change of this ratio to a great extent depends on the dynamic characteristics of the elastic system of the used turning machine. At high dynamic rigidity of the machine and the tool, this ratio could alter not so significantly but the experiments show that the decrease in amplitude of the high frequency component of the vibration signal, according to the wear of the cutting edge at marble processing displays normally.

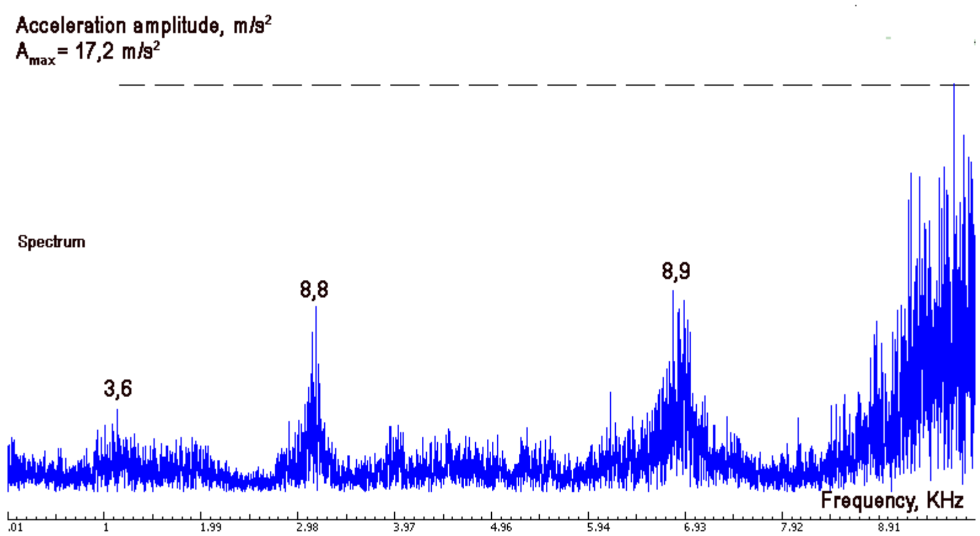

Fig. 8. Spectrum of the vibroacceleration at turning of marble with a sharp cutter.

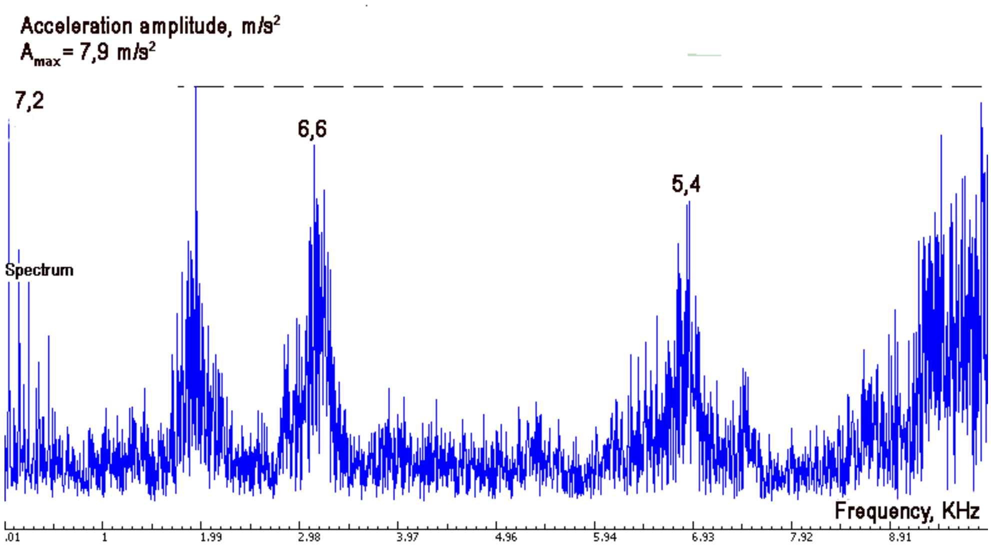

Fig. 9. Spectrum of the vibroacceleration at turning of marble with a blunt tool.

Let examine the summary of oscillating movements of the cutter point, which are consequences of its oscillations along the axes and bring to deviations of the surface shape (roughness).

The co-ordinate connection reveals as follows: in general case under the influence of the force applied, the cutter point strives to move not only in the direction of the cutting force, but also in orthogonal direction. It happens because of the tool unit different rigidity in the different directions, i. e. main axes of rigidity ξ_1 and ξ_2 exist, which usually do not coincide with the co-ordinate axes Z and X of the machine (Кудинов В. А., 1967).

Fig. 10 shows the amplitude-frequency and phase-frequency characteristic of a turning machine along the axis Z, at application of impact force along the axis Z, according fig. 7. If an impact force is applied along the axis X, as well as at the first example a movement is observed along the axis Z and its frequency characteristics are presented in fig. 11.

This way, the joint movements of the cutter point along the axes Z and X appear even in case when the force action is directed along one axis, which brings not only to deviation of dimensions, but also to deviation of the surface quality.

The trajectory of the cutter point movement in octave 1000 Hz at operation with a sharp cutter is shown in fig. 12 and with a blunt cutter in fig. 13.

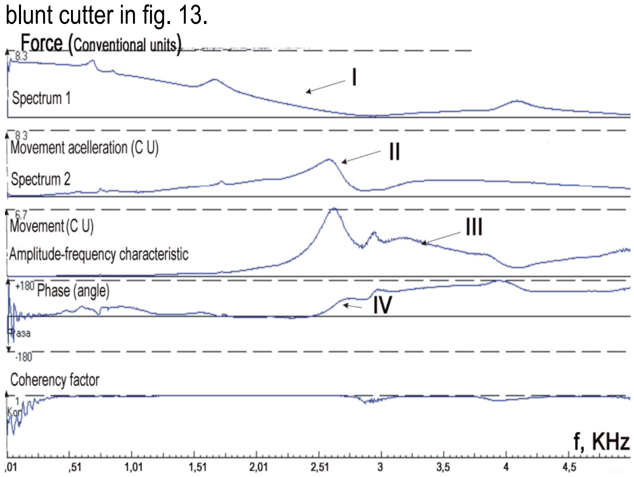

Fig. 10. Amplitude-frequency and phase-frequency characteristics of a turning machine along the axis Z, at application of impact force along the axis Z, acoording fig. 7. I- Impact spectrum (excitation, input signal) ; II – Movement spectrum (oscillations; output signal, reaction to the excitation) ; III - amplitude-frequency characteristic of the machine elastic system; IV - phase-frequency characteristic of the machine elastic system.

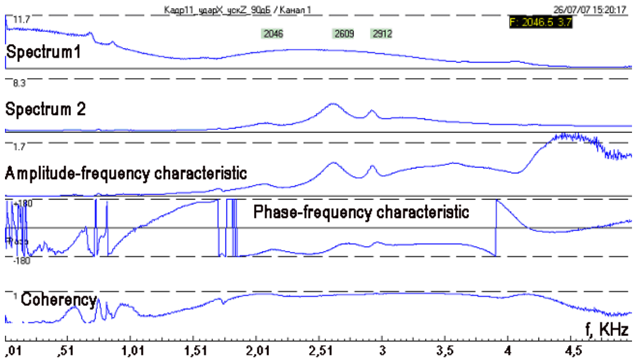

Fig. 11. Amplitude-frequency and phase-frequency characteristics of a turning machine along the axis Z, at application of impact force along the axis X, according fig. 7.

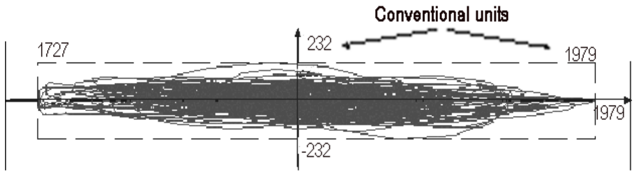

Fig. 12. Trajectory of the cutter point movement in octave 1000 Hz at operation with a sharp cutter.

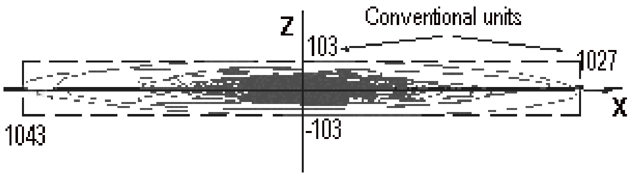

Fig. 13. Trajectory of the cutter point movement in octave 1000 Hz at operation with a blunt cutter.

It could be seen that the lack of chip provokes big deviations along the normal to the surface depreciating its roughness.

The units along the axes are conventional, because the ratio of amplitudes is important in this case.

It could be seen that the oscillations along the normal predominate over the tangential. Such a type of trajectory is typical of operation with a sharp and blunt tool. At the contour processing, this brings to worsening of the anyway unfavorable conditions.

The spectrums of the cutter natural frequencies along the axes Z and X at vertical impacts on the cutter point, are presented in figures 14 and 15. These spectrums are connected both to the blunt and sharp cutter.

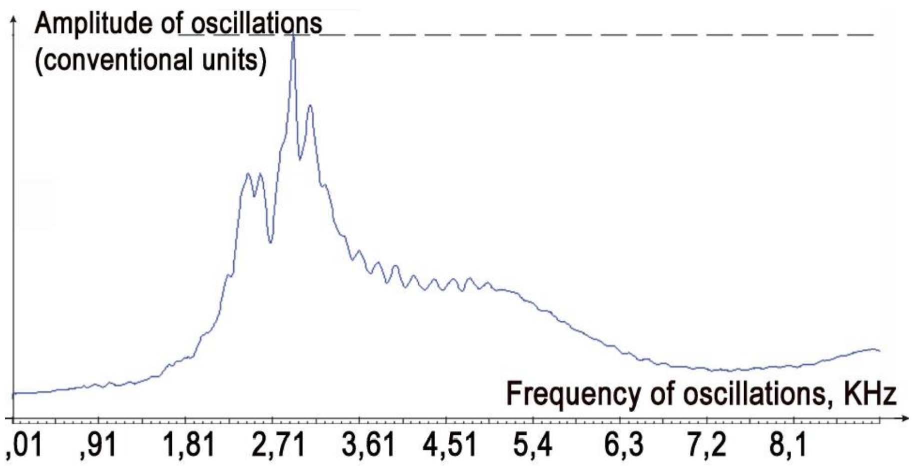

Fig. 14. Spectrum of the cutter natural frequencies along the axis Z at vertical impacts on the cutter point

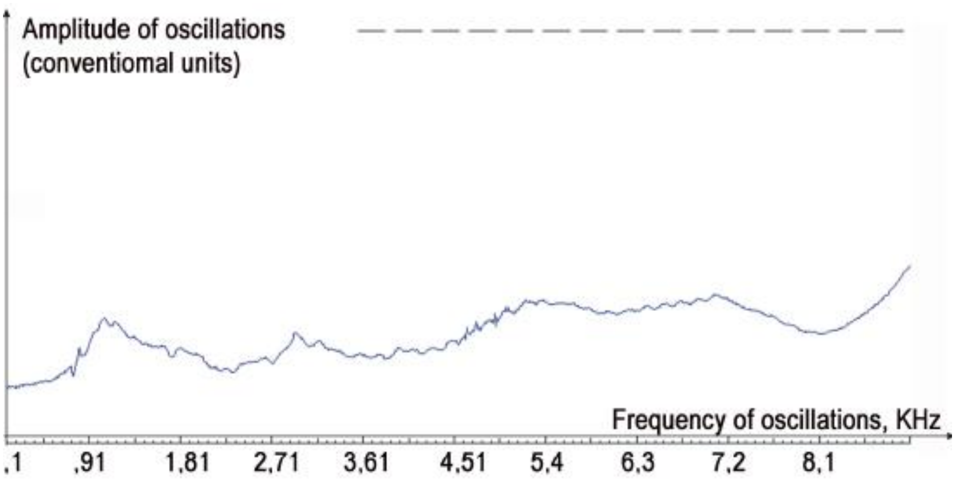

Fig. 15. Spectrum of the cutter natural frequencies along the axis X at vertical impacts on the cutter point.

From these figures follows that at determination of technological regimes influencing the frequency of the variable component of the cutting force, it has to be taken into account that this component coincidence with one of the tool natural frequencies will bring to increase in forced oscillations and respectively to deviation of the surface shape.

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