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ACOUSTIC RADIATION ENERGY AT A VARIATION OF THE COMPOSITE MECHANICAL DESTRUCTION AREA

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Abstract

Purpose: *The technological parameters of composite materials machining and also cutting tool state determine deforming and destruction of their surface layers conditions. Change of this conditions results to appearance of miscellaneous defects, loss of quality and produced items reliability. Therefore, optimization, control, diagnosis and monitoring of composite materials machining technological parameters are directed on obtaining the items given quality. For the solution of these problems tasks carry out researches of technological processes with usage of different methods. One of such methods is the acoustic emission method.* ***Methods:*** *The simulation and analysis of acoustic radiation energy parameters is carried out at change of composite material machining depth for prevailing mechanical destruction its surface layer.* ***Results:*** *We showed that to composite material machining the acoustic radiation energy has continuous nature. The ascending of composite material machining depth results to increase of acoustic emission statistical energy parameters. The regularity of acoustic emission energy parameters change are obtained and described. Is showed, that acoustic radiation most sensing parameter is the acoustic emission signals energy average level dispersion.* ***Discussion:*** *The outcomes researches demonstrate regularity influencing of composite material machining depth on acoustic emission energy parameters. Thus the analysis of acoustic emission signals energy average level dispersion can be used at mining methods of diagnostic, monitoring and control of composite materials machining technological parameters.*

Keywords: acoustic emission; composite material; control; energy; machining; model; resultant signal.

1. Introduction

Optimization and control of machining composite materials (CM) technological parameters are directed on obtaining of items given quality. For the solution of these problems the different methods will be used. One of such methods is the method of an acoustic emission (AE).

Researches of AE during machining demonstrate that the AE method is mirrored dynamics weep processes destruction of CM surface layer. The method has a sharp response, which is mirrored in change of nature and parameters of AE registered signals. However the acoustic radiation is influenced by many factors. Such factors are the parameters of machining technological processes, and as properties of treated and treating CM. As demonstrate researches, the availability of the influential factors results in a problem of interpretation the registered information. Thus the obtained of AE parameters regularity changes have complicated nature. It limits usage of AE method to the monitoring and control of CM machining technological parameters.

With given the points of view, the value has simulation of acoustic radiation processes at CM machining, with allowance for operating different factors. Influencing of such factors on regularity of AE parameters change is the basis for optimization of CM machining technological parameters, and as mining of methods for verification, monitoring and control of CM machining technological processes. The solution of these problems is directed on items quality assurance from CM.

2. Analysis of the latest research and publications

The researches of AE at fulfillment of different machining operations demonstrate, that the continuity deforming and destruction of CM surface layer process, as well as stuffs with crystalline frame, is accompanied by formation of continuous acoustic radiation [1 - 4]. At fulfillment of CM machining operation is not watched transformations of acoustic radiation nature. However at wearing (destruction) of the treating tool there is a change of registered AE signals parameters - decreasing of AE signal amplitude average level and value of its spread [5-7]. At the same time, the outcomes researches demonstrate that the acoustic radiation is influenced by CM machining technological parameters. According to the data in the article [6], the ascending of machining speed results to nonlinear ascending AE signal amplitude mean and root mean square (RMS) value, and as standard deviations of amplitude average value. Ascending of a cutting depth and the stride cutting tool speeds result in composite nature of AE signals amplitudes mean and RMS value change, and as its standard deviation. On the obtained relations is watched both ascending, and dip of parsed AE signals parameters. In the article [8], it is shown, that the ascending of machining speed and cutting depth results in increase of AE signal amplitude (amplitude average level). Thus the relations of AE signal amplitude change have practically linear nature of ascending. In the article [9] is marked, that the ascending of machining speed results to nonlinearity increasing of AE signals RMS amplitudes value. Thus the ascending of cutting depth and stride cutting tool speed is accompanied by a linearity increasing of AE signals amplitudes RMS value.

The outcomes of researches demonstrate, that the machining technological parameters have ambiguity influencing on parameters of registered acoustic radiation. Such ambiguity results in restricted application of AE method for the monitoring and control of CM machining technological processes, inclusion and CM.

From this point of view, value has analytical investigations of acoustic radiation at CM machining, with allowance of the different operating factors. In the article [10] the simulation and analysis of legitimacies AE signals amplitude parameters change is conducted at CM machining for termoactivative model of its surface layer destruction, with allowance of the different operating factors. Such factors were machining speed, cutting depth and physical-mechanical characteristics of CM. It is shown, that the ascending of cutting depth (area of surface layer destruction) results in a linear increasing of AE signal amplitude average level and value of its deviation. Thus the dispersion of AE signal amplitude average level has nonlinear nature of ascending. The relations of AE amplitude parameters percentage increment from a percentage increment of CM machining speed, cutting depth and physical-mechanical characteristics of CM are obtained. Is determined, that the increment or the dip of AE resultant signals amplitude dispersion average level, depending on the influential factor, advances the increment or the dip of amplitude average level and its standard deviation.

At the same time, the concern introduces research of influencing of CM machining cutting depth for the mechanical model of its surface layer destruction. First of all, it falls into of acoustic energy radiation, as most capacious AE parameter.

3. Research tasks

The purpose of activity is the research of influencing of CM machining cutting depth for the mechanical model of its surface layer destruction on AE energy parameters. For achievement of this purpose were put the following tasks: to conduct simulation of AE energy in time at change of CM machining cutting depth for the mechanical model of its surface layer destruction; to conduct statistical processing of simulation results with definition of numerical data on statistical AE energy parameters; to determine influencing of CM machining cutting depth on AE energy parameter.

4. Researches results

Let us consider the process of CM machining. CM has the given physical-mechanical characteristics. Let's consider that the destruction of CM surface layer descends at the prevailing mechanism of mechanical destruction. With allowance for conditions of formation acoustic radiation at CM machining, which reviewed in the article [11], amplitude pulse and AE resultant signal energy are described by the following expressions

$$U_{jM}(t) = u_0 t\alpha\upsilon_0 e^{r\alpha t} e^{-\frac{\upsilon_0}{r\alpha}(e^{r\alpha t}-1)}, \quad (1)$$

$$E_p(t) = \sum_j E_{jM}(t - t_j), \quad (2)$$

where u_0 - maximum possible elastic displacement, which spread in the material during instant destruction of the given CM area; α – load speed; υ_0, r – constants, which are determined by CM physical and mechanical characteristics; $t_j = j\Delta t_j \pm \delta$ – moments of time when AE signals appear with energy E_{jM}, which appear during sequential mechanical destruction of CM *j-th* areas; j – number of CM destructed area or a number of formed AE pulse signal (j=0, 1,…, n); Δt_j – is time interval between the beginning of the next AE impulse signal generation in regard to the previous one; δ – random component in a moment of time when each next AE pulse signal appear; $E_{jM} \sim U_{jM}^2$; U_{jM} – amplitudes of *j-th* AE signal.

In expression (1) parameter u_0 is connected to the area of CM destruction

$$u_0 = N_0 \psi \delta_S , \quad (3)$$

where N_0 – quantity of single CM elements in the given destruction area; ψ – aspect ratio between mechanical stress and amplitude of disturbance single-pulse, which one is reshaped at single CM elements destruction (is a constant); δ_S – the value, which one is proportional to disturbance pulse duration at single CM elements destruction.

The ascending of quantity destruction elements N_0 corresponds to increase of the CM elementary destruction area.

For the account of CM destruction area expression (1) we shall copy by the way

$$U_{jM}(t) = \eta u_0 t \alpha \upsilon_0 e^{r\alpha t} e^{-\frac{\upsilon_0}{r\alpha}(e^{r\alpha t}-1)} , \quad (4)$$

where $\eta = N_T / N_0$ – coefficient, that describing increase of initial value of quantity CM elements (of the destruction area); N_0 – initial value of quantity CM elements; N_T – current value of quantity CM elements.

At a solving, agrees (2) and (4), we shall consider, that there is an increase of CM destruction area, i.e. there is an increase of quantity CM elements N_T, in relation to initial quantity of CM elements N_0, or the value η will be increase. At simulation value η in relative units we shall change from $\tilde{\eta}$ =1 up to $\tilde{\eta}$ =3 with a step of increment 0,5.

Simulation of acoustic radiation energy will be conducted with the next conditions. The parameters, which one are included in expressions (2) and (4), we shall put to non-dimensional values. Amplitude of signals we shall set norms on value u_0. At simulation the values of parameters υ_0, r and α will be taken the same as well as in the article [11]: $\tilde{\upsilon}_0$ = 100000, $\tilde{r}$ = 10000; $\tilde{\alpha}$ = 20. For value $\tilde{\alpha}$ = 20 value Δt_j will be taken as $\Delta \tilde{t}_j$ = 0,000011. The value $\tilde{\delta}$ we will change in the diapason from 0 to 0,000011 arbitrarily.

Results of the performed modeling in the form of dependencies AE resultant signals energy change in time in the relative units for different values of CM destruction areas (parameter $\tilde{\eta}$) are shown in the fig. 1. In the graphs fig.1 time is normalized by the time of the CM surface layer destruction process. During the formation of graphs in the fig. 1 the calculations 5000 amplitudes and, accordingly, energies for each AE resultant signal are conducted.

Obtained results (fig. 1) show that with an increase of cutting depth a change of acoustic radiation character doesn't occur. AE signals in time are represented as a continuous signal with the strongly cut up form. At the same time, with an increase of cutting depth ascending of AE resultant signals average energy level and value of its deviation is observed. In tab. 1 the data of statistical processing of simulation results are adduced, where the following notations are adopted: $\tilde{\tilde{E}}$ – AE signal energy average level; $s_{\tilde{\tilde{U}}}$ – AE signal standard deviation of energy average level; $s_{\tilde{\tilde{U}}}^2$ – AE signal dispersion of energy average level.

According to the data of tab. 1, on fig. 2 regularity of AE signal energy average level change, its standard deviations and dispersions are adduced depending on CM machining cutting depth.

The approximating of the data has shown, that the relations of AE signal energy average level change and its standard deviation (fig. 2, *a, b*) are well described by linear functions of kind

$$\tilde{Z} = a + b\tilde{\eta} , \quad (5)$$

where $\tilde{\tilde{Z}}$ - AE signal energy average level or its standard deviation; *a* and *b* – coefficients of approximating expression.

The values of coefficients a and b of approximating expression (5) make: for the AE signal energy average level - a= -0,001, b=0,00122; for the standard deviation of AE signal energy average level - a= -8,25844$\cdot 10^{-4}$, b=1,07097; for the dispersion of AE signal energy average level - a= 7,7716$\cdot 10^{-9}$, b=0,00103. Thus correlation coefficients R at the description of AE resultant signal energy average level and its standard deviations, accordingly, make: R=0,99509; R=0,99578. Selection criteria of approximating functions for the description of relations fig. 2, *a, b*, would be the minimum of residual dispersion.

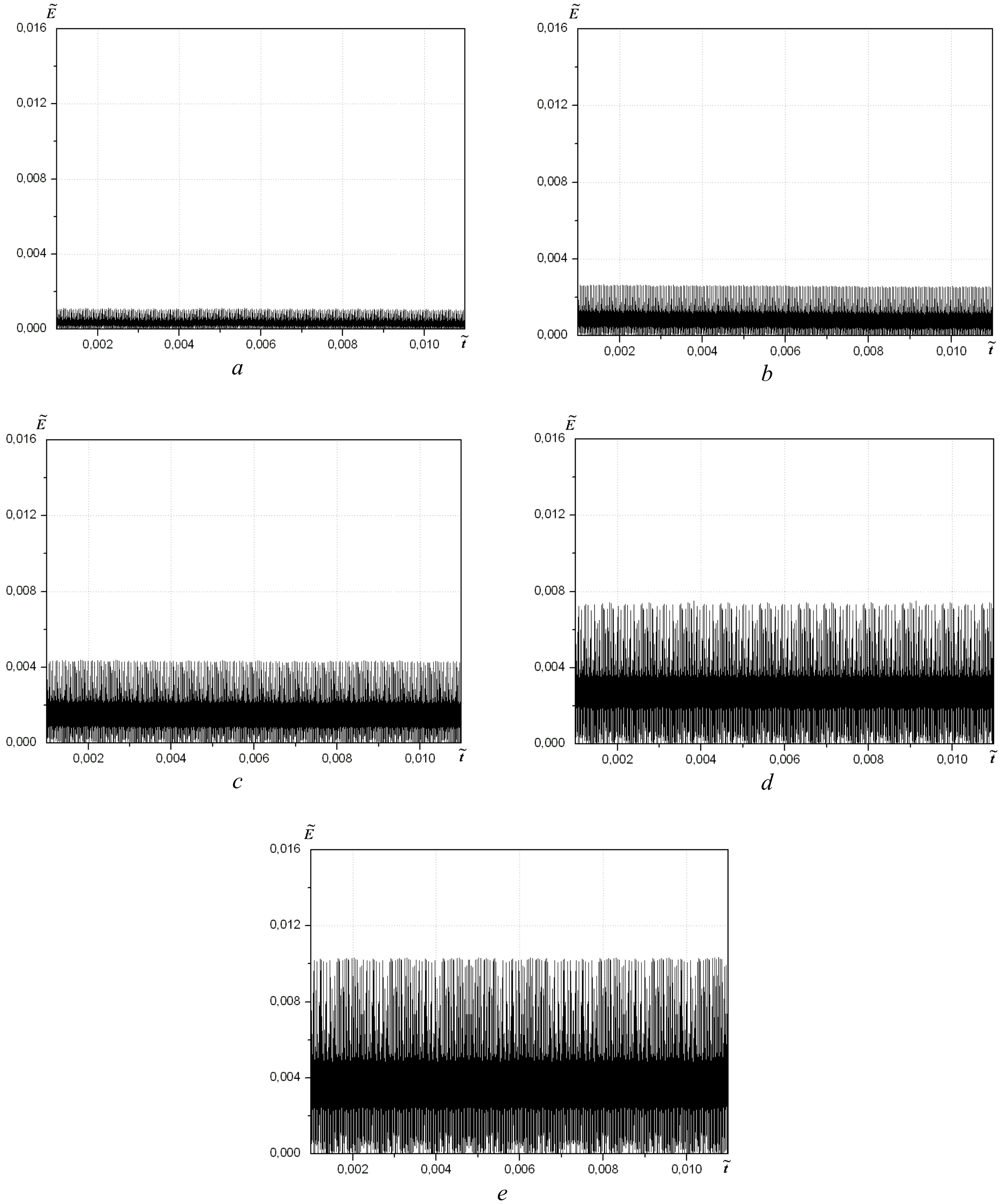

Fig. 1. Graphs of AE resultant signals energy change in time, according to (2), in relative units during the CM machining for the prevailing mechanical destruction of its surface layer and different cutting depth. Modeling parameters: $\tilde{\upsilon}_0$=100000, $\tilde{r}$ = 10000; $\tilde{\alpha}$ = 20. Starting value $\widetilde{\Delta t}_j$=0,000011. Parameter $\tilde{\delta}$ should be changed in diapason from 0 to up 0,000011 arbitrarily. CM machining cutting depth in relative units: *a* - $\tilde{\eta}$=1,0; *b* - $\tilde{\eta}$=1,5; *c* - $\tilde{\eta}$=2,0; *d* - $\tilde{\eta}$=2,5; *e* - $\tilde{\eta}$=3,0

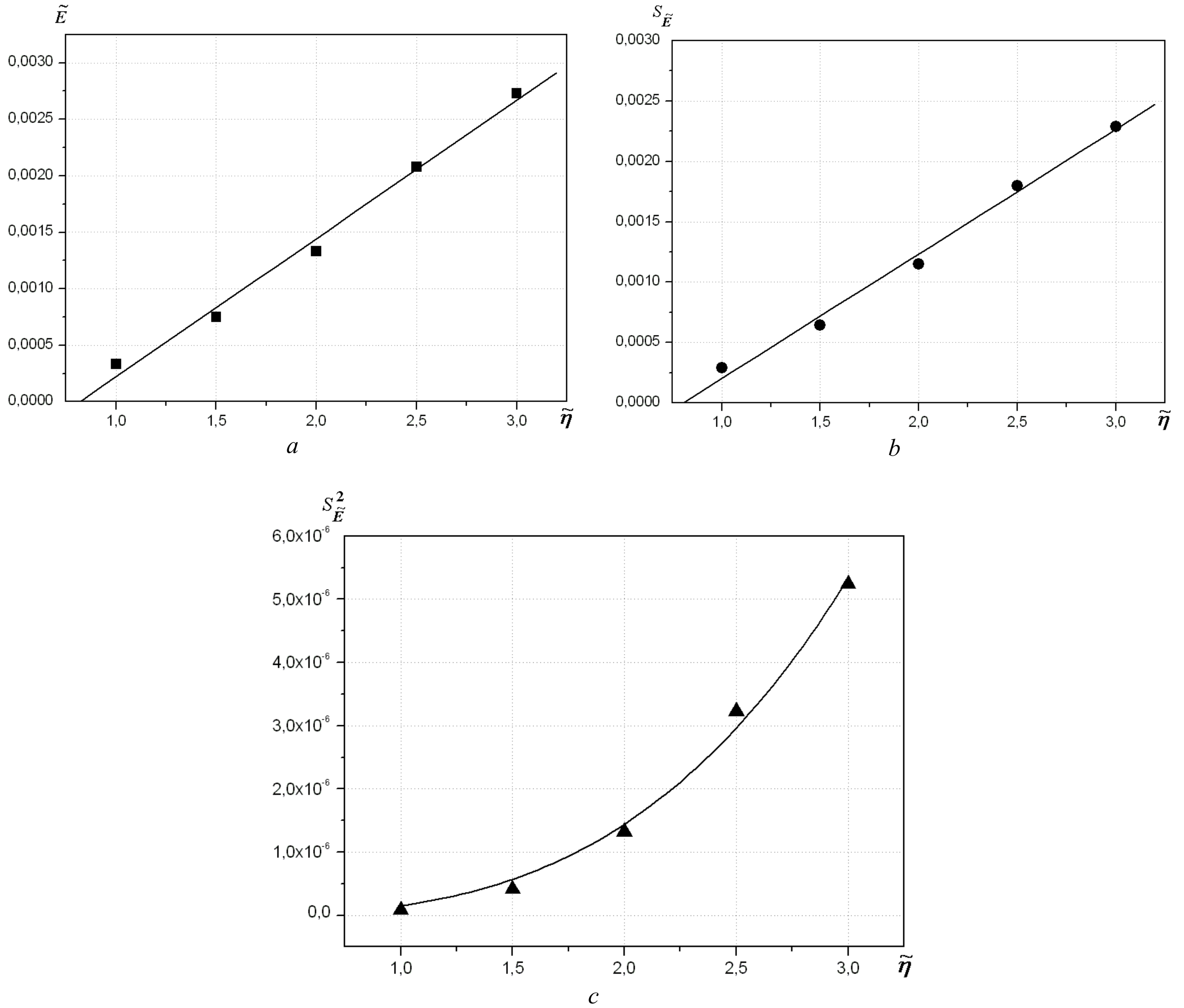

Fig. 2. Graphs of change of AE resultant signals energy average level $\tilde{\tilde{E}}$ (■), its standard deviation $s_{\tilde{\tilde{E}}}$ (●) and dispersion $s^2_{\tilde{\tilde{E}}}$ (▲) depending on CM machining cutting depth ($\tilde{\eta}$)

Table 1. Energy parameters of AE resultant signal at ascending of CM machining cutting depth

$\tilde{\eta}$	$\tilde{\tilde{E}}$	$s_{\tilde{\tilde{U}}}$	$s^2_{\tilde{\tilde{U}}}$
1	$3,34977 \cdot 10^{-4}$	$2,8945 \cdot 10^{-4}$	$8,37812 \cdot 10^{-8}$
1,5	$7,49193 \cdot 10^{-4}$	$6,46764 \cdot 10^{-4}$	$4,18304 \cdot 10^{-7}$
2	0,00133	0,00115	$1,32205 \cdot 10^{-6}$
2,5	0,00208	0,0018	$3,22765 \cdot 10^{-6}$
3	0,00273	0,00229	$5,24416 \cdot 10^{-6}$

The relation of AE signal energy average level dispersion change (fig. 2, *c*) is well described by function of kind

$$s^2_{\tilde{\tilde{E}}} = c\tilde{\eta}^d \quad , \qquad (6)$$

where *c* and *d* – coefficients of approximating expression.

The values of coefficients *c* and *d* of approximating expression (6) make: c=1,5399·10^{-7} ; d=3,2277. Thus determination coefficients R^2 at the description of AE resultant signal energy average level dispersion (fig. 2, *c*) by expression (6) make: R^2=0,99352. Selection criteria of approximating functions for the description of relations fig. 2, *c* would be the minimum of residual dispersion.

For definition sensitivity of AE signals energy parameters to ascending of CM machining cutting depth we shall conduct data processing (tab. 1) with definition of percentage increment of AE signal energy parameters at ascending of cutting depth, in relation to their initial values at $\tilde{\eta}$ =1,0.

The results of data processing are shown in fig. 3, where the following notations are adopted: $\Delta\tilde{Z}$ - percentage increment of AE resultant signal energy average level or its standard deviation or dispersion; $\tilde{\eta}$ - CM machining cutting depth.

The results are shown that for the prevailing mechanical destruction CM surface layer the increase of cutting depth should result in to ascending of AE signals energy parameters (tab. 1, fig. 2, fig. 3). Thus with ascending of CM machine depth the percentage increment of AE signal energy

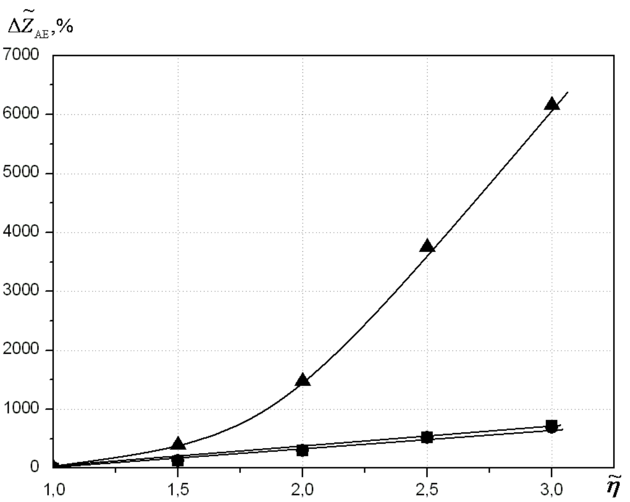

Fig. 3

Graphs of the percentage increment of AE resultant signals energy change depending on CM machining cutting depth ($\tilde{\eta}$) for the prevailing mechanical destruction surface layer: energy average level $\tilde{\tilde{E}}$ (■), its standard deviation $s_{\tilde{\tilde{E}}}$ (●) and dispersion $s^2_{\tilde{\tilde{E}}}$ (▲) average level dispersion advances a percentage increment of energy average level and its standard deviation (fig. 3). Truly, at ascending CM cutting depth in 2,5 times (with $\tilde{\eta}$ =1,0 up to $\tilde{\eta}$ =2,5) percentage increment of AE signals energy parameters (energy average level $\tilde{\tilde{E}}$, its standard deviation $s_{\tilde{\tilde{U}}}$ and dispersions $s^2_{\tilde{\tilde{U}}}$), accordingly, make: 521,26 %, 520,68 % and 3752,48 %. At ascending CM cutting depth in 3,0 times (up to value $\tilde{\eta}$ =3,0) percentage increment of AE signals energy parameters, accordingly, make: 714,98%, 691,16% и 6159,35%.

6. Conclusions

The modeling of acoustic radiation energy in time is carry out depending on CM machining cutting depth for the mechanical model surface layer destruction. Is determined, that the ascending of CM machining cutting depth does not result on acoustic radiation nature change. Energy of AE signals in time has a continuous character of change. However increase of AE signal energy average level and value of its deviation is watched. The data processing is conducted. The statistical AE signals energy parameters at ascending of CM machining cutting depth are determined. Are described the regularity of AE signal energy average level, its standard deviations and dispersions change at ascending of CM machining cutting depth. It is shown, that regularity of AE resultant signal average energy level change and its standard deviations are well described by linear functions, and dispersions of energy average level - exponential function The relations of AE energy parameters percentage increment at ascending of CM machining cutting depth are obtained. Thus shown, that most sensing AE parameter is the dispersion of AE signal energy average level, i.e. the percentage increment of AE signal energy average level dispersion advances a percentage increment of energy average level and its standard deviation at ascending CM machining cutting depth. The results of the conducted researches demonstrate that the analysis of AE resultant signal energy average level dispersion can be used at mining methods of verification and monitoring by CM machining processes for the control of cutting depth.

At the same time, it is interesting to research influencing of CM physical-mechanical characteristics on AE energy parameters at its machining.

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С.Ф. Філоненко. Еенергія акустичного випромінювання при варіації площі механічного руйнування композита

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Мета: Технологічні параметри механічної обробки композиційних матеріалів, а також стан різального інструменту визначають умови деформування й руйнування їхніх поверхневих прошарків. Зміна цих умов призводить до появи різноманітних дефектів, втрати якості і надійності виробів, які виготовляються. Оптимізація, контроль, діагностика й моніторинг технологічних процесів механічної обробки композиційних матеріалів спрямовані на отримання заданої якості виробів. Для розв'язання цих завдань проводять дослідження технологічних процесів з використанням різних методів. Одним із таких методів є метод акустичної емісії. **Методи:** Проводиться моделювання з аналізом енергетичних параметрів акустичного випромінювання при зміні глибини механічної обробки композиційного матеріалу для переважного механічного руйнування поверхневого прошарку. **Результати:** Показано, що при механічній обробці композиційного матеріалу енергія акустичного випромінювання має неперервний характер. Зростання глибини механічної обробки композиційного матеріалу призводить до збільшення статистичних енергетичних параметрів акустичної емісії. Отримано й описано закономірності зміни енергетичних параметрів акустичної емісії. Показано, що найбільш чутливим параметром акустичного випромінювання є дисперсія середнього рівня

енергії сигналів акустичної емісії. **Обговорення**: Результати досліджень показують закономірності впливу глибини механічної обробки композиційного матеріалу на енергетичні параметри акустичної емісії. При цьому аналіз дисперсії середнього рівня енергії сигналів акустичної емісії може використовуватися при розробці методів діагностики, моніторингу й управління параметрами технологічних процесів механічної обробки композиційних матеріалів.
Ключові слова: акустична емісія; енергія; композиційний матеріал; механічна обробка; модель; результуючий сигнал; управління.

С.Ф. Филоненко. Энергия акустического излучения при вариации площади механического разрушения композита

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Цель: Технологические параметры механической обработки композиционных материалов, а также состояние режущего инструмента определяют условия деформирования и разрушения их поверхностных слоев. Изменение данных условий приводит к появлению разнообразных дефектов, потере качества и надежности изготавливаемых изделий. Оптимизация, контроль, диагностика и мониторинг технологических процессов механической обработки композиционных материалов направлены на получение заданного качества изделий. Для решения данных задач проводят исследования технологических процессов с использованием различных методов. Одним из таких методов является метод акустической эмиссии. **Методы:** Проводится моделирование с анализом энергетических параметров акустического излучения при изменении глубины механической обработки композиционного материала для преобладающего механического разрушения поверхностного слоя. **Результаты:** Показано, что механической обработке композиционного материала энергия акустического излучения имеет непрерывной характер. Возрастание глубины механической обработки композиционного материала приводит к увеличению статистических энергетических параметров акустической эмиссии. Получены и описаны закономерности изменения энергетических параметров акустической эмиссии. Показано, что наиболее чувствительным параметром акустического излучения является дисперсия среднего уровня энергии сигналов акустической эмиссии. **Обсуждение**: Результаты исследований показывают закономерности влияние глубины механической обработки композиционного материала на энергетические параметры акустической эмиссии. При этом анализ дисперсии среднего уровня энергии сигналов акустической эмиссии может использоваться при разработке методов диагностики, мониторинга и управления параметрами технологических процессов механической обработки композиционных материалов.
Ключевые слова: акустическая эмиссия; композиционный материал; механическая обработка; модель; результирующий сигнал; управление; энергия.

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