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INFORMATIVE OF EXPERIMENTAL ACOUSTIC EMISSION SIGNALS PARAMETERS IN TECHNOLOGICAL PROCESSES MACHINING COMPOSITE

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Abstract

Purpose: *The aim of this article is the experimental study of machining composite speed effect on the acoustic emission energy parameters.* ***Methods:*** *The studies were based on the recording and processing of experimental acoustic emission signals during the composite material machining. The statistical processing of experimental acoustic emission signals with an analysis of the acoustic radiation energy parameters was made.* The *analysis of acoustic emission statistical energy parameters regularities change and their sensitivity to machining composite speed changes was made, as well as a comparison sensitivity of acoustic radiation energy and amplitude parameters.* ***Results:*** Is obtained, that at composite machining speed ascending there is increasing of experimental acoustic emission signals energy average level and value of its spread. *Thus the greatest increasing is watched in acoustic radiation energy average level dispersion. Is determined, that the experimental acoustic emission signals statistical energy parameters have not linear nature of ascending. The ascending of experimental acoustic emission signals energy parameters advances ascending their amplitude parameters.* ***Discussion:*** *The experimental researches of acoustic radiation energy parameters at ascending of composite machining speed are conducted. The statistical data processing has shown, that a regularity of acoustic radiation signal energy average level ascending, its standard deviation and the dispersions are well described by exponential functions. Thus is shown, that the greatest sensitivity to ascending of composite machining speed there is the experimental acoustic emission signals energy average level dispersion. A comparison of acoustic emission amplitude and energy parameters has shown, that the percentage increment of experimental signals energy average level dispersion advances a percentage increment of energy average level and its standard deviation, and as increment of all acoustic radiation statistical amplitude parameters The outcomes of the conducted researches can be used at the decision some problems: optimization of machining process parameters; development of methods verification, monitoring and control the technological processes parameters.*

Keywords: Acoustic emission; composite; energy; machining; parameters; signal

1. Introduction

The manufacturing of products using the machining methods causes a wide range of studies. The researches, first of all, are directed on optimization technological processes parameters to ensure stable conditions for contact interaction between the processed and processing materials. Thus various parameters are measured and analyzed. Regularity of these parameters change is the basis in creating methods, and also systems for verification, monitoring and controlling of materials machining processes. The carried out researches, in full measure, cover also composite materials (CM) machining. One of the researches methods is the method of acoustic emission (AE).

The obtained results demonstrate composite nature of acoustic radiation, which is influenced by the CM machining technological parameters, physical and mechanical characteristics treated and treating materials, and also condition of the treating tool. The change of the influential factors values, as demonstrate researches, results in change of contact interplay conditions, and, as a consequent, to change in the acoustic radiation parameters. Taking into account the low inertia and high sensitivity of AE method, receive considerable amounts information about deformation and destruction processes of the materials surface layers, including and CM. However, it results in a problem of interpretation registered AE information. The solution of the problem is based on obtaining and analyzing the results of theoretical and experimental studies AE parameters at operating the different factors. Such researches allow determining informative and regularity of AE parameters change at operating the different factors, to conduct optimization CM machining parameters, to design methods of verification, monitoring and control technological processes.

2. Analysis of the latest researches and publications

The high requirements to reliability of items produced with usage machining operations, requires optimization, verification, monitoring and control of technological processes parameters. To solve these problems, various researches methods are used, including and AE method [1–5]. Such research of technological processes is carried out during materials machining with crystalline structure and CM.

The results of researches demonstrate a high sensitivity of AE method to change of contact interaction conditions treated and treating CM, which are determined by change of influencing factors values. Thus a lot of regularities acoustic radiation parameters change, first of all, bound with CM machining parameters change are obtained.

In article [6] is obtained, that at ascending of material machining speed there is an increasing of registered AE signals amplitude root mean square (RMS) value. The relation has practically linear nature of ascending. The similar influencing on AE signals amplitude RMS renders of treating tool longitudinal speed and cutting depth. Is determined, that at increasing of machining speed and cutting depth there is decreasing of treated surface roughness. However, at increasing of tool longitudinal speed is accompanied by ascending of treated surface roughness. Thus is marked, that AE has a high sensitivity to change of treated surface roughness. In article [7], investigations of AE signal RMS amplitude at wearing of treating tool are conducted. It is shown that with increasing tool wear there is ascending of registered AE signals RMS amplitude. Thus, as the writers of article have marked [7], for automation of tool state monitoring process it is necessary to use of AE signals filtration in definite frequency bands. Investigations of influencing machining technological parameters on AE, carried out in article [8], have shown, that with increasing cutting depth, as a rule, the increase of AE signal RMS amplitude is observed. At higher cutting speeds and depths, despite the reduction in cutting force, the AE signal RMS amplitude there is increases. However, increase of AE signal RMS amplitude is not significant. In article [9] is shown, that to ascending of CM machining speed and decreasing of cutting depth there is decreasing AE investigated parameters. Such parameters are: AE events count rate, AE events number, AE events energy. At the same time, in article [10] is obtained, that at ascending of machining speed there is increasing of AE statistical amplitude parameters. Thus of AE signals amplitude average level, AE signals RMS amplitude and AE signal amplitude average level standard deviation have not linear nature of ascending. The coefficients excess and asymmetry of amplitude distribution at ascending machining speed have composite nature of change. The researches also demonstrate that the ascending of cutting depth and longitudinal speed results in composite nature of AE registered signals all statistical amplitude parameters change. The similar nature of AE statistical amplitude parameters change is watched at ascending of treating tool wear. In article [11], when studying the effect of CM machining speed and cutting depth, is shown that the increasing of machining speed results in linear increasing of registered AE signal amplitude. At the same time, the relation of AE signals amplitude on the cutting speed has a composite nature of change at large cutting depths.

In article [12] the outcomes experimental and analytical investigations of AE signals at ascending of CM machining speed are reviewed. It is shown, that the experimental AE signals are continuous signals. With ascending of CM machining speed is watched ascending an of AE signals amplitude average level, standard deviation of AE signals amplitude average level and its dispersion. The processing of AE signals statistical amplitude parameters (amplitude average level, amplitude average level standard deviation and its dispersion) the outcomes of simulation has shown the good agreement with outcomes of the experimental studies. In articles [13, 14] the analytical investigations of acoustic radiation energy at ascending of CM machining speed are conducted. It is shown, that increasing of CM machining speed results in increase of AE signals energy average level and its spread. The regularities of AE signal energy average level change, its standard deviation and dispersion are obtained and described with increasing of CM machining speed. Is determined, that of the most sensing AE parameters to increasing CM machining speed is of AE signal energy average level dispersion - percentage increment of AE signal energy average level dispersion advances a percentage increment of energy average level and its standard deviation.

At the same time, for mining authentic methods of verification, monitoring and controls technological processes the interest introduces obtaining and research of experimental acoustic radiation energy parameters change at CM machining speed change.

3. Research tasks

The aim of this article is the experimental researches of AE energy parameters at change of CM machining speed.

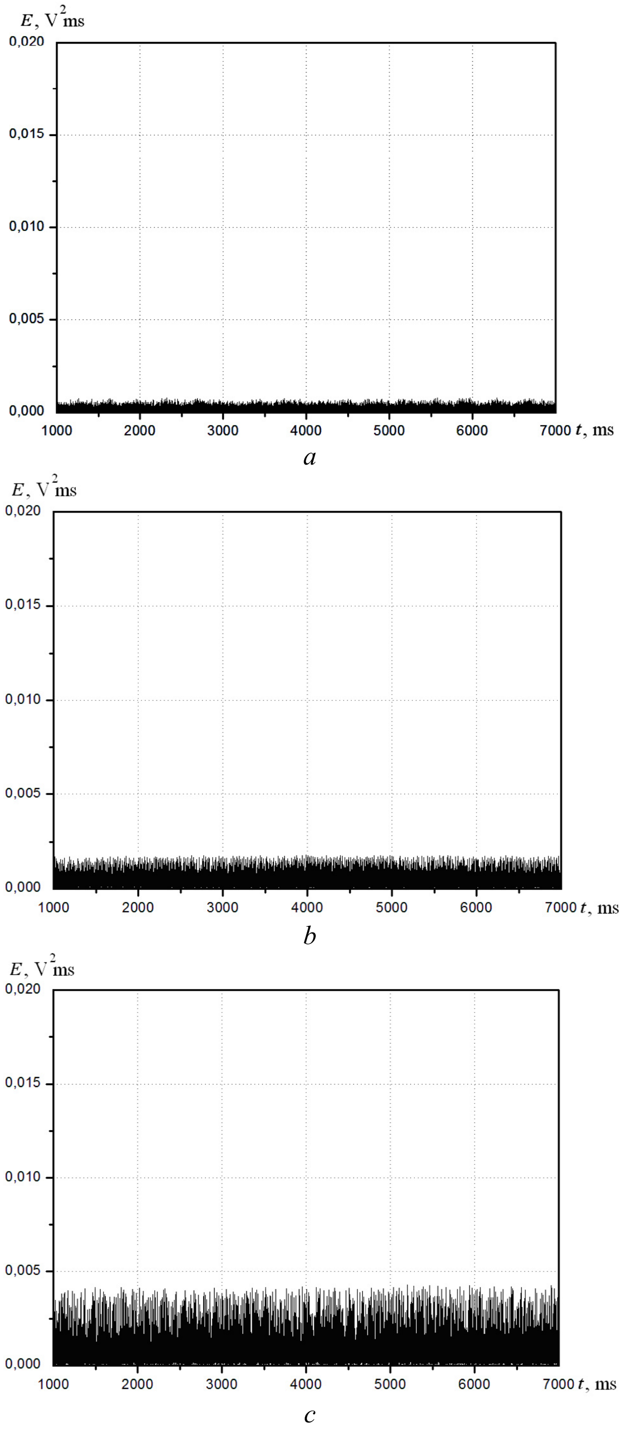
For achievement the purpose of article the following problems were put: - to conduct experimental researches of influencing CM machining speed on the AE energy parameters; - to conduct processing of experimental AE signals with data retrieval on statistical AE energy parameters; - to determine of AE statistical energy parameters regularity change at ascending of CM machining speed; - to determine sensitivity of statistical AE energy parameters to ascending of CM machining speed; - to conduct matching sensitivity AE statistical amplitude and energy parameters to ascending of CM machining speed.

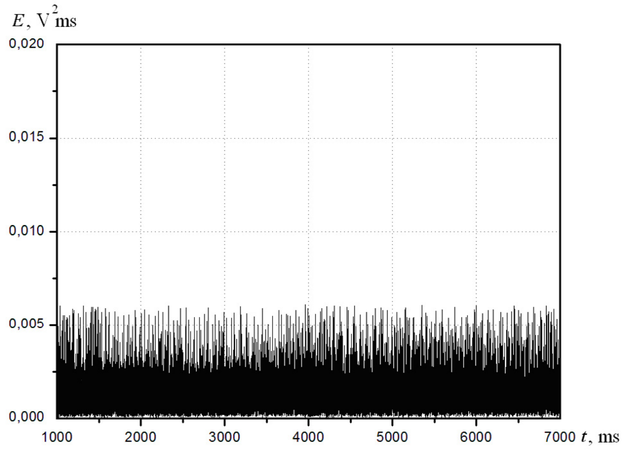
4. Researches results

Experimental researches of acoustic radiation energy parameters at CM machining we shall conduct in accordance with the methodology and used materials, which are reviewed in article [12]. Thus the parameters of machining will be equal: cutting depth - 0,1 mm; treating tool longitudinal feed speed - 0,1 mm/rev. Cutting speed will make: 100 m/min, 200 m/min, 300 m/min, 400 m/min, 500 m/ min.

Registration of AE signals and their processing, as well as in article [12], will be carried out using AE sensor, which is placed on the tool holder, and an AE system. When carrying out data analysis, we will use the tabular and graphical results of experimental acoustic radiation energy parameters representation.

In Fig. 1 the acoustic radiation energy relations change in time at different CM machining speeds are shown.





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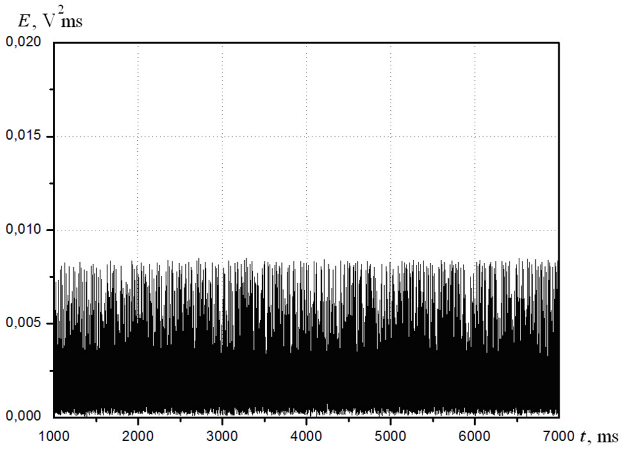

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Fig. 1. Graphs of experimental AE signals energy change in time for different of CM machining cutting speeds. The values of machining parameters: tool longitudinal feed speed is 0.1 mm/rev, machining depth is 0.1 mm. The values of machining parameters: cutting depth - 0,1 mm; treating tool longitudinal feed speed - 0,1 mm/rev. Cutting speed: *a* - 100 m/min; *b* - 200 m/min; *c* - 300 m/min; *d* - 400 m/min; *f* - 500 m/ min

The experimental results demonstrate (Fig. 1) that at CM machining the AE signals energy has continuous nature of radiation. At constant values of treating tool longitudinal feed speed and cutting depth the increase of machining speed results in ascending registered AE signal energy average level and value of its spread.

Really, as the statistical data processing (tab. 1) has shown, ascending of CM machining speed in 2 times (from 100 m/ min up to 200 m/min) results in ascending of acoustic radiation signal energy average level, its standard deviation and dispersion, accordingly, in 3.05 times, in 3.51 times and in 12.30 times. If the CM machining speed increases in 3 times (from 100 m/min up to 300 m/min) then the acoustic radiation signal energy average level, its standard deviation and dispersion increase, accordingly, in 6.46 times, in 8.40 times and in 70.52 times. Ascending of CM machining speed in 4 times (from 100 m/min up to 400 m/min) results in increase of acoustic radiation signal energy average level, its standard deviation and dispersion, accordingly, in 10.34 times, in 12.27 times and in 150.48 times. If the CM machining speed increases in 5 times (from 100 m/min up to 500 m/min) then the acoustic radiation signal energy average level, its standard deviation and dispersion increase, accordingly, in 16.08 times, in 19.90 times and in 395.91 times.

Table 1

Statistical energy parameters of experimental AE signals

Machining speed, m/min	$\overline{E}$, V²ms	$s_{\overline{E}}$, V²ms	$s_{\overline{E}}^2$, V⁴ms²
100	$1.52 \cdot 10^{-4}$	$8.34 \cdot 10^{-5}$	$6.96 \cdot 10^{-9}$
200	$4.63 \cdot 10^{-4}$	$2.93 \cdot 10^{-4}$	$8.56 \cdot 10^{-8}$
300	$9.80 \cdot 10^{-4}$	$7.01 \cdot 10^{-4}$	$4.91 \cdot 10^{-7}$
400	0.00157	0.00102	$1.05 \cdot 10^{-6}$
500	0.00244	0.00166	$2.76 \cdot 10^{-6}$

In tab. 1 the following notations of AE signal energy parameters are adopted: $\overline{E}$ - AE signal energy average level; $s_{\overline{E}}$ - AE signal energy average level standard deviation; $s_{\overline{E}}^2$ - AE signal energy average level dispersion.

In Fig. 2 are shown the regularity of acoustic radiation energy average level, its standard deviation and dispersion depending on CM machining speed. From a fig. 2 it is visible, that the experimental AE signals statistical energy parameters relations changes have a not linear nature of ascending that will be agreed with the results of analytical investigations [14].

The statistical data processing with approximating relations, reduced in Fig. 2, has shown, that they are well described by an exponential function of the form

$$A_{\overline{E}} = aV^b, \quad (1)$$

where $A_{\overline{E}}$ - acoustic radiation signal energy average level of either its standard deviation or dispersion; *a, b* - approximating expression factors; *V* - CM machining speed.

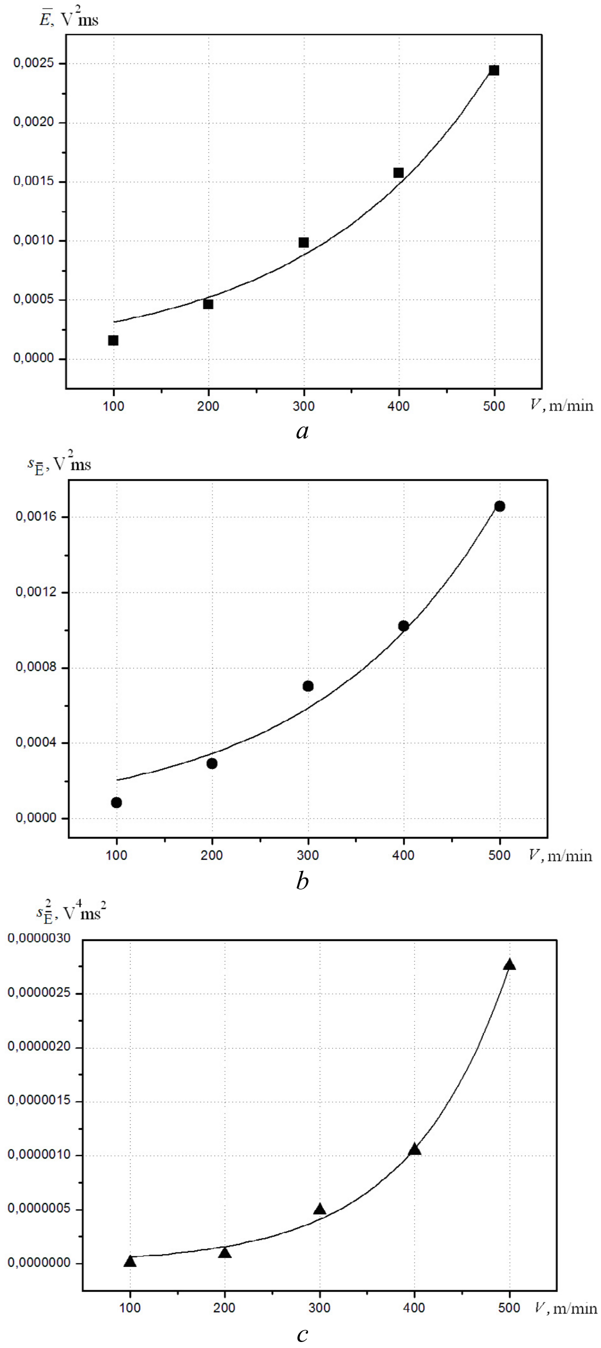

Fig. 2. Relations of experimental AE energy average level change $\overline{E}$ (*a*), its standard deviation $s_{\overline{E}}$ (*b*) and dispersion $s_{\overline{E}}^2$ (*c*) at ascending of CM machining speed (*V*)

The values of approximating expression (1) factors *a* and *b* are make: for the experimental AE signal energy average level - a=$3.0921 \cdot 10^{-8}$, b=1.81316; for the experimental AE signal energy average level standard deviation - a=$1.8299 \cdot 10^{-8}$, b=1.83473; for the experimental AE signal energy average level dispersion - a=$7.2598 \cdot 10^{-17}$, b=3.91846. Thus determination factors R^2 for the experimental AE signal energy average level, its standard deviation and dispersions, accordingly, make: R^2 =0.99899; R^2 =0.9947, R^2 =0.99529. Yardstick of approximating functions selection at the description relations on Fig. 2 was the minimum residual dispersion.

For definition sensitivity of experimental AE signals statistical energy parameters to ascending of machining speed we shall conduct calculations of their percentage increment. Calculations we shall conduct in relation to initial values of statistical AE signals energy parameters at initial CM machining speed 100 m/min. The outcomes of the conducted calculations are shown in Fig. 3 (*a*).

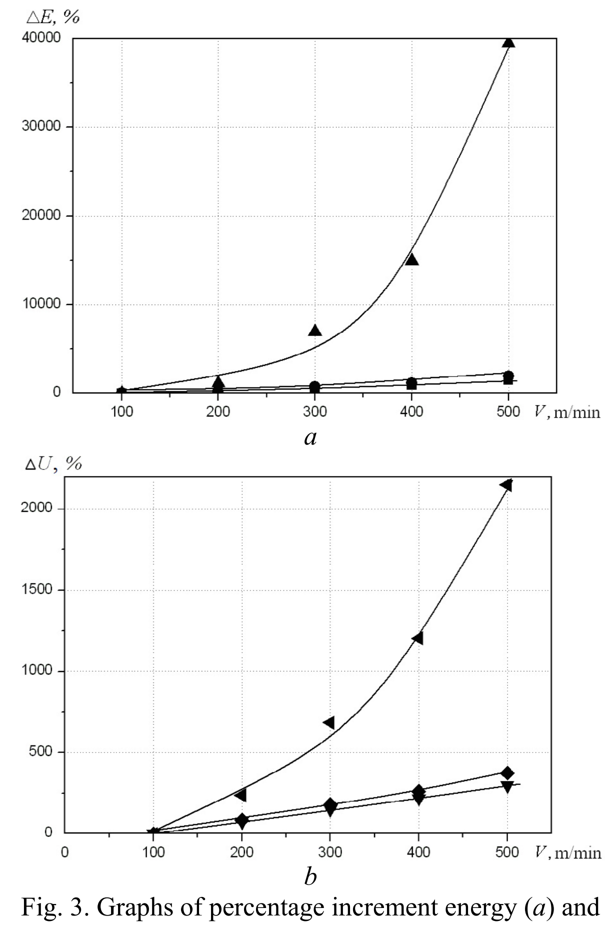

Fig. 3. Graphs of percentage increment energy (*a*) and amplitude (*b*) experimental AE signals parameters in velocity function of CM machining: a - energy average level $\overline{E}$ (■), its standard deviation $s_{\overline{E}}$ (●) and dispersion $s_{\overline{E}}^2$ (▲); b - amplitude average level $\overline{U}$ (▼), its standard deviation $s_{\overline{U}}$ (◄) and dispersion $s_{\overline{U}}^2$ (◆)

From the obtained outcomes (Fig. 3, *a*) is visible, that ascending of CM machining speed results in the greatest percentage increment of AE signals energy average level dispersion. So, at ascending machining speed in 4 times (from 100 m/min up to 400 m/min) percentage increment of acoustic radiation signal energy average level ($\overline{E}$), its standard deviation ($s_{\overline{E}}$) and dispersion ($s^2_{\overline{E}}$), accordingly, are augmented: on 934.28%, on 1126.65% and on 14946.72%. At ascending machining speed in 5 times (from 100 m/min up to 500 m/min) percentage increment of acoustic radiation statistical energy parameters ($\overline{E}$, $s_{\overline{E}}$ and $s^2_{\overline{E}}$), accordingly, are augmented: on 1508.02%, on 1889.75% and on 39491.05%. In other words, the most sensing and informative parameter of registered AE signals to CM machining speed is an acoustic radiation energy average level dispersion.

For matching sensitivity AE amplitude and energy parameters in Fig. 3, *b* the relations of percentage increment AE signals statistical amplitude parameters at ascending of CM machining speed are shown [15].

From Fig. 3, *a, b* it would be visible, that at ascending machining speed percentage increment of registered AE signals energy parameters advances a percentage increment of their amplitude parameters. As demonstrate calculations, at ascending machining speed from 100 m/min up to 400 m/min a percentage increment of acoustic radiation signal energy average level, its standard deviation and dispersion is advanced a percentage increment of acoustic radiation signal amplitude average level, its standard deviations and dispersion, accordingly, in 4.28 times, in 4.32 times and in 12.41 times. At ascending machining speed up to 500 m/min the percentage increment of acoustic radiation signal energy average level, its standard deviation and dispersion is advanced a percentage increment of acoustic radiation signal amplitude average level, its standard deviations and dispersion, accordingly, in 5.1 times, in 5.06 times and in 18.38 times. The obtained outcomes demonstrate that the most sensing parameter of acoustic radiation to ascending CM machining speed is the AE signal energy average level dispersion.

6. Resume

The outcomes of experimental acoustic radiation energy parameters research are adduced at ascending of CM machining speed. The data on registered AE signals statistical energy parameters are obtained. It is shown that to ascending machining speed there is not a linear ascending of acoustic radiation energy parameters. The regularity ascending of acoustic radiation signal energy average level, its standard deviations and dispersions are obtained, which one are well described by exponential functions. The calculations of acoustic radiation statistical energy parameters percentage increment are conducted at ascending of CM machining speed. The sensitivity of acoustic radiation energy parameters to ascending machining speed is determined. It is shown, that the percentage increment of experimental AE signals energy average level dispersion advances a percentage increment of energy average level and its standard deviation. Matching sensitivity amplitude and energy parameters of acoustic radiation to alteration of machining speed is conducted. It is shown, that most sensing parameter of acoustic radiation is the registered AE signals energy average level dispersion, its increment advances increment of all acoustic radiation energy and amplitude parameters.

The outcomes of the conducted researches can be used at the decision some problems: optimization of machining process parameters; development of methods verification, monitoring and control the technological processes parameters. In further researches the concern is introduced by experimental researches of machining depth influencing on acoustic radiation amplitude parameters.

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С.Ф. Філоненко[1], О.В. Заріцький[2]. Інформативність параметрів експериментальних сигналів акустичної емісії в технологічних процесах механічної обробки композита

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Мета: Метою роботи є експериментальні дослідження впливу швидкості механічної обробки композита на енергетичні параметри акустичної емісії. **Методи дослідження:** Дослідження були засновані на реєстрації та обробці експериментальних сигналів акустичної емісії при механічній обробці композиційного матеріалу. Була проведена статистична обробка експериментальних сигналів акустичної емісії з аналізом енергетичних параметрів акустичного випромінювання. Був проведений аналіз закономірностей зміни статистичних енергетичних параметрів акустичної емісії та їх чутливості до зміни швидкості механічної обробки композита, а також порівняння чутливості енергетичних та амплітудних параметрів акустичного випромінювання. **Результати:** Отримано, що при зростанні швидкості механічної обробки композита відбувається зростання середнього рівня енергії експериментальних сигналів акустичної емісії та величини його розкиду. При цьому найбільше зростання спостерігається у дисперсії середнього рівня енергії акустичного випромінювання. Визначено, що статистичні енергетичні параметри експериментальних сигналів акустичної емісії мають не лінійний характер зростання. Зростання енергетичних параметрів експериментальних сигналів акустичної емісії випереджає зростання їх амплітудних параметрів. **Обговорення:** Проведені експериментальні дослідження енергетичних параметрів акустичного випромінювання при зростанні швидкості механічної обробки композита. Статистична обробка даних показала, що закономірності зростання середнього рівня енергії сигналу акустичного випромінювання, його стандартного відхилення і дисперсії добре описуються степеневими функціями. При цьому показано, що найбільшу чутливість до зростання швидкості механічної обробки композита має дисперсія середнього рівня енергії експериментальних сигналів акустичної емісії. Порівняння амплітудних і енергетичних параметрів акустичної емісії показало, що процентний приріст дисперсії середнього рівня енергії експериментальних сигналів випереджає процентний приріст середнього рівня енергії та його стандартного відхилення, а також приріст всіх статистичних амплітудних параметрів акустичного випромінювання. Результати проведених досліджень можуть використовуватися при рішенні ряду задач: оптимізація параметрів процесу механічної обробки композита; розробка методів контролю, моніторингу та управління параметрами технологічних процесів.

Ключові слова: акустична емісія; енергія; композит; механічна обробка; параметри; сигнал

С.Ф. Филоненко[1], О.В. Зарицкий[2]. **Информативность параметров экспериментальных сигналов акустической эмиссии в технологических процессах механической обработки композита**
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Цель: Целью работы является экспериментальные исследования влияния скорости механической обработки композита на энергетические параметры акустической эмиссии. **Методы исследования:** Исследования были основаны на регистрации и обработке экспериментальных сигналов акустической эмиссии при механической обработке композиционного материала. Была проведена статистическая обработка экспериментальных сигналов акустической эмиссии с анализом энергетических параметров акустического излучения. Был проведен анализ закономерностей изменения статистических энергетических параметров акустической эмиссии и их чувствительность к изменению скорости механической обработки композита, а так же сравнение чувствительности энергетических и амплитудных параметров акустического излучения. **Результаты:** Получено, что при возрастании скорости механической обработки композита происходит возрастание среднего уровня энергии экспериментальных сигналов акустической эмиссии и величины его разброса. При этом наибольшее возрастание наблюдается в дисперсии среднего уровня энергии акустического излучения. Определено, что статистические энергетические параметры экспериментальных сигналов акустической эмиссии имеют не линейный характер возрастания. Возрастание энергетических параметров экспериментальных сигналов акустической эмиссии опережает возрастание их амплитудных параметров. **Обсуждение:** Проведены экспериментальные исследования энергетических параметров акустического излучения при возрастании скорости механической обработки композита. Статистическая обработка данных показала, что закономерности возрастания среднего уровня энергии сигнала акустического излучения, его стандартного отклонения и дисперсии хорошо описываются степенными функциями. При этом показано, что наибольшую чувствительность к возрастанию скорости механической обработки композита имеет дисперсия среднего уровня энергии экспериментальных сигналов акустической эмиссии. Сравнение амплитудных и энергетических параметров акустической эмиссии показало, что процентный прирост дисперсии среднего уровня энергии экспериментальных сигналов опережает процентный прирост среднего уровня энергии и его стандартного отклонения, а так же прирост всех статистических амплитудных параметров акустического излучения. Результаты проведенных исследований могут использоваться при решении ряда задач: оптимизация параметров процесса механической обработки композита; разработка методов контроля, мониторинга и управления параметрами технологических процессов.

Ключевые слова: акустическая эмиссия; композит; механическая обработка; параметры; сигнал; энергия

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