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INFLUENCING OF COMPOSITE MACHINING SPEED ON EXPERIMENTAL REGULARITY OF ACOUSTIC EMISSION AMPLITUDE PARAMETERS CHANGE

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Abstract**—***The experimental regularity of acoustic emission amplitude parameters change at ascending of composite material machining speed is reviewed. Is determined, that ascending of acoustic emission signal amplitude average level and its standard deviations are described by linear functions. The regularity of acoustic emission signal amplitude average level dispersion change is described by a power function. The sensitivity of acoustic emission amplitude parameters to an alteration of composite material machining speed is determined. It is shown, that the percentage increment of acoustic emission signals amplitude average level dispersion advances a percentage increment of amplitude average level and its standard deviation. It is shown, that experimental and idealized regularity of acoustic emission signals statistical amplitude parameters change at ascending of composite material machining speed have good agreement with each other.*

Index Terms—Acoustic emission; composite material; signal; amplitude; machining; control; statistical characteristics.

I. INTRODUCTION

In the manufacture of products using machining operations, one of the problems is the problem of ensuring the quality a produced surface. It is particular importance in the manufacture of products from composite materials (CM). First of all, this is due to the need to prevent damage the surface layers of treated CM (at all levels). The solution of the problem is based on a wide range of CM machining technological processes studies with development the methods of their diagnosis, monitoring and control. During researches various methods are used, among which the method of acoustic emission (AE) is singled out. This is due to the high sensitivity and low inertia of the method to the internal processes that occur in the materials structure when they are loaded.

Acoustic emission investigations in machining CM cover all types of executed operations. Thus the influence of various factors on acoustic radiation and its interrelations with the quality of the manufactured products is analyzed. Such analysis involves solving a number of problems. At first, the optimization of the technological processes parameters for a pair of interacting materials (treated and treating materials). Secondly, the obtaining regularities influencing of various factors on acoustic radiation with determination of the sensitivity and informative of AE parameters, that is the basis for developing methods for verification, monitoring and controlling the CM machining technological processes. However, it should be noted that large volumes of recorded information and its modification under changing conditions of interaction pair contact materials lead to the problem of interpretation the registered information. The problem is aggravated by the presence of a large number of the influencing factors, one of which is the machining speed. Unconditionally, that determination the laws of its influence on the acoustic radiation parameters, as the basis for monitoring and controlling the machining process, is of undoubted interest.

II. STATEMENT OF THE TASK

The purpose of this article is the experimental and theoretical studies of influencing CM machining speed on the regularity of AE amplitude parameters change.

To achieve these aims next tasks were set: to conduct researches with definition of experimental regularities of AE amplitude parameters change at an alteration of CM machining speed; to conduct statistical data processing with the mathematical description of the obtained regularities of AE amplitude parameters change; to determine sensitivity of AE amplitude parameters to the change of CM machining speed; to conduct matching experimental and idealized outcomes.

III. REVIEW OF PUBLICATIONS

Experimental studies of machining materials processes, including and CM, show that the detected AE signals are continuous signals [1] – [5]. The

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change of technological processes parameters (machining speed, cutting depth, feed speed) does not influence of acoustic radiation nature. However results in change of AE registered signals amplitude-energy parameter. Obtained regularity for each technological parameter, as demonstrate researches, have a broad spectrum of changes and in many cases are discordant.

One of the parameters a machining technological process is the cutting speed. In article [6], during experimental studies it was shown that with increasing CM machining speed for given temperature cutting conditions, the root mean square (RMS) value of the AE registered signals amplitudes is decreases. At the same time, in article [7] is determined, that ascending of CM machining speed results in ascending of AE signal RMS amplitude. Thus the obtained relation practically has linear nature of ascending. The similar influencing on AE signals RMS amplitude has also feed speed. However, as the authors of the paper note, the unstable connection from AE signals RMS amplitude with increasing machining depth is watched.

The research of influencing CM machining speed and cutting depths on AR registered signals parameters is reviewed in article [8]. It is shown, that at low of cutting depths the ascending of machining speed results in ascending of AE registered signal amplitude. The obtained relations have linear nature of ascending. However at large cutting depths the relation of AE signals amplitude from a cutting speed has composite and unstable character of change. The similar relations are also observed at increase of cutting depth for a preset machining speed. In article [3] is shown, that ascending of CM machining speed results in change of AE signals RMS amplitude. However relations have composite nature of change. Ascending of AE signals RMS amplitude at first is observed, and then it dips. The gentle influencing of machining speed on AE was also noted in article [9].

In article [10] the research of influencing CM machining speed, cutting depth and feed speed on AE amplitude parameters is conducted. The outcomes researches have shown that the ascending of machining speed results in increase of AE registered signals amplitude average value and RMS amplitude. Thus the regularity of their change has not linear nature of ascending. Also is determined, that the ascending of machining speed results in non-linear ascending of AE signals amplitude average value standard deviation. However at ascending a cutting depth and feed speed the relation of AE amplitude parameters change have composite and not unequivocal nature. The analysis of influencing CM machining speed on AE at different cutting depths and feed speeds is conducted in article [11]. It is shown, that at low cutting depths for all feed speeds relation of AE signals RMS change have composite nature of change (are watched ascending and dip the values of analyzed parameters). At the same time, at large depths of cutting the relation of AE signals RMS change has a pronounced increasing character for all investigated longitudinal speeds of the tool. In article [12] influencing of CM machining speed on AE parameters was investigated, such as: AE count; AE number of events; AE energy. The results of the conducted researches have shown that the ascending of machining speed leads to a drop in all the AE investigated parameters.

Analytical and experimental researches of AE amplitude parameters are conducted in articles [13], [14]. Analytical investigations [13] were conducted at CM machining for a case of its prevailing mechanical destruction surface layer. The results of research showed that the generated AE signals are continuous signals. To increasing of machining speed there is ascending of AE signal amplitude average level and value its deviation. Thus the regularity of AE signal amplitude average level and its standard deviations change have linear nature of ascending. At the same time, the regularity of AE signal amplitude average level dispersion change has not linear nature of ascending. Experimental researches of AE at CM machining [14] also have shown that to increasing of machining speed there is ascending of AE signal amplitude average level and value of its deviation. From the point of view of AE usage for optimization and control of CM machining technological parameters, the concern introduces the AE amplitude parameters legitimacies change description at ascending of CM machining speed, and also definition of their sensitivity.

III. RESULTS OF EXPERIMENTAL RESEARCHES

Experimental studies of AE during CM machining that carried out in [14] showed that the detected AE signals are continuous signals. Thus ascending of CM machining speed there is ascending of AE signal amplitude average level and value of its deviation. The research technique and technological modes of machining investigated material are reviewed in article [14]. During the research, the machining depth and longitudinal speed of the tool were constant. The cutting speed ranged of values from 100 m/min up to 500 m/min. The incremental velocity step of cutting speed made 100 m/min. The results of statistical processing AE registered signals amplitude parameters for different machining speeds are given in Table I, where the following notations are accepted: AE signal amplitude average level

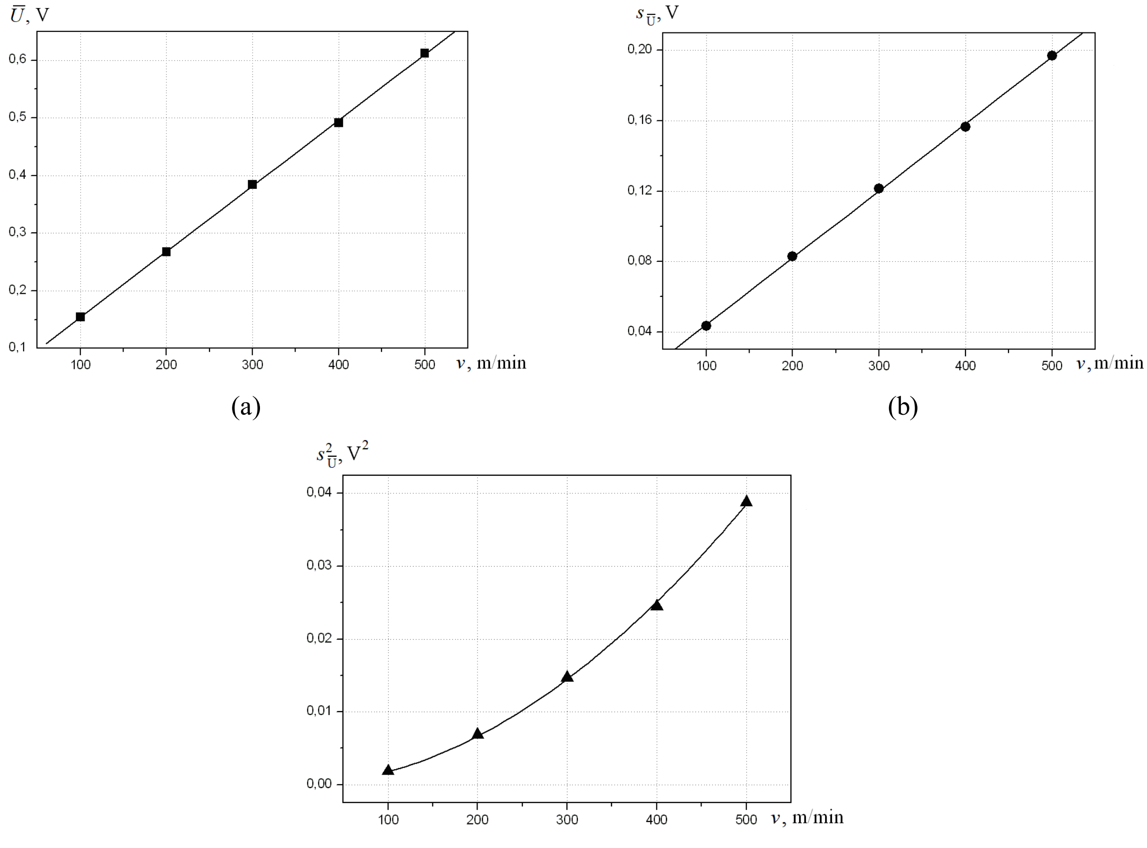
($\overline{U}$); AE signal amplitude average level standard deviation ($s_{\overline{U}}$); AE signal amplitude average level dispersion ($s_{\overline{U}}^2$).

TABLE I. AMPLITUDE PARAMETERS OF EXPERIMENTAL AE SIGNALS

Machining speed, m/min	$\overline{U}$, V	$s_{\overline{U}}$, V	$s_{\overline{U}}^2$, V^2
100	0.1544	0.04341	0.00188
200	0.26753	0.08299	0.00689
300	0.38446	0.12137	0.01473
400	0.49147	0.15658	0.02452
500	0.61227	0.19694	0.03879

According to the obtained data (Table I) we shall conduct construction and mathematical description of AE signals statistical amplitude parameters legitimacies change at ascending of investigated material machining speed.

In Fig. 1 the relations of AE signal amplitude average level change, its standard deviation and dispersion from machining speed are adduced. The obtained results demonstrate (Fig. 1) that the increase of machining speed conducts to ascending all AE registered signals statistical amplitude parameters. Thus the AE registered signal amplitude average level and its standard deviation (Fig. 1a, b) have a linear character of the increase. At the same time, AE registered signal amplitude average level dispersion (Fig. 1c) has not linear nature of ascending.



(c)

Fig. 1. Relations of AE amplitude average level change $\overline{U}$ (a), its standard deviation $s_{\overline{U}}$ (b) and dispersion $s_{\overline{U}}^2$ (c) at ascending of CM (silumin-based) machining speed (v)

The analysis of the obtained data with approximating relations, reduced in a Fig. 1a, b, would show, that they is well described by expression of the form

$$z = a + bv\,, \tag{1}$$

where z is AE registered signal amplitude average level or its standard deviation; a and b are coefficients of approximating expression.

The values coefficients a and b of approximating expression (1) make: for AE signal amplitude average level – a = 0.04012, b = 0.00114; for AE signal amplitude average level standard deviation – a = 0.00606, b = 3.80652 $\cdot 10^{-4}$. Thus correlation coefficients R for AE registered signal amplitude average level and its standard deviations, accordingly, make: R = 0.99988; R = 0.9998.

At approximating dependencies shown in Fig. 1a, b, the criterion for choosing the approximating expression (1) was the minimum of residual standard deviation.

The approximating relation of AE signals amplitude average level dispersion change, reduced on Fig. 1c, has shown, that she is well described by expression of the form

$$s_{\bar{U}}^2 = cv^d, \qquad (2)$$

where c and d are coefficients of approximating expression.

The values coefficients c and d of approximating expression (2) make: $c = 2.6305 \cdot 10^{-7}$, $d = 1.91393$. At the describing dependence shown in Fig. 1b, expression (2), the determination coefficient R^2 is $R^2 = 0.99935$.

At approximating dependencies shown in Fig. 1c, the criterion for choosing the approximating expression (2) was the minimum of residual dispersion.

For definition sensitivity of AE signals statistical amplitude parameters to ascending CM machining speed we shall conduct processing of their percentage increment. The results of calculations percentage increase of experimental AE signals amplitude average level, their standard deviation and dispersion at increasing of CM machining speed, relative to their initial values at initial machining speed of 100 m/min, are shown in Fig. 2.

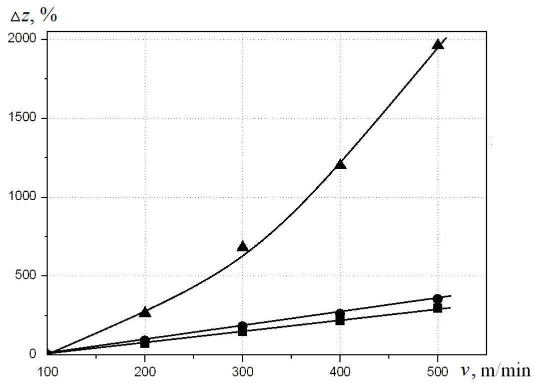
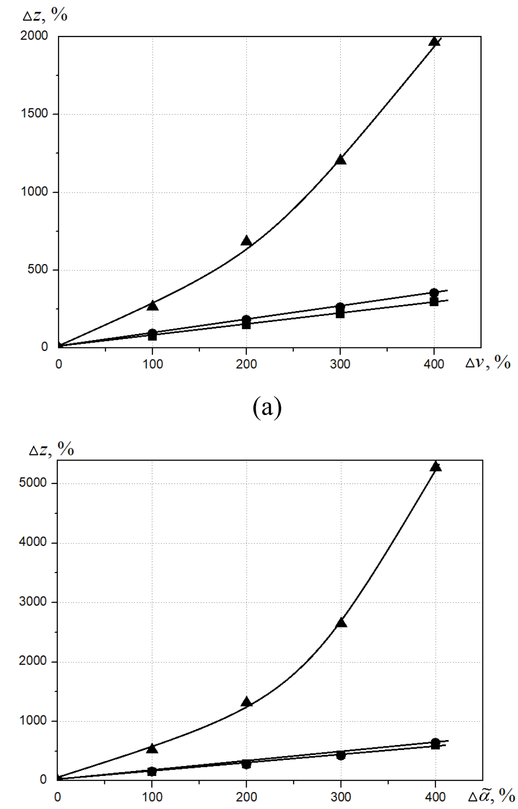


Fig. 2. Dependences the change of AE signal amplitude average level percentage increase $\bar{U}$ (■), its standard deviation $s_{\bar{U}}$ (●) and dispersion $s_{\bar{U}}^2$ (▲) at increasing CM (silumin-based) machining speed (v), with respect to their initial values at initial machining speed of 100 m/min

The obtained results (Fig. 2) demonstrate that at ascending CM machining speed the greatest percentage increase is observed in AE signals amplitude average level dispersion. Really, at ascending machining speed in 4 times (from 100 m/min up to 400 m/min) percentage increment of AE signals amplitude average level, their standard deviations and dispersions, accordingly, makes: 218.31 %, 260.70 %, 1204.07 %. If the CM machining speed increases in 5 times (from 100 m/min up to 500 m/min), percentage increment of AE signals amplitude an average level, their standard deviations and dispersions, accordingly, makes: 296.55 %, 353.682 % and 1963.12 %.

From the results of the conducted researches it is evident that the most sensitive AE amplitude parameter to increase of CM machining speed is the AE signals amplitude average level dispersion.

For matching outcomes experimental and theoretical investigations of influencing CM machining speed on AE signals statistical amplitude parameters in Fig. 3 the relations of their percentage increase on percentage increase cutting speed are shown. The percentage increase of AE signals statistical amplitude parameters was calculated, relative to their initial values at the initial machining speed. The percentage increase of machining speed was carried out with respect to the initial machining speed.



(b)

Fig. 3. Dependences of the AE signal amplitude average level percentage increase change $\bar{U}$ (■), its standard deviation $s_{\bar{U}}$ (●) and dispersion $s_{\bar{U}}^2$ (▲) on the percentage increase of CM machining speed (v, $\tilde{\alpha}$), in respect to their values at the initial machining speed: *a* are experimental dependences; *b* are theoretical dependences

From the obtained results (Fig. 3), it can be seen that the experimental and theoretical dependences of the AE signals statistical amplitude parameters percentage increase on the machining speed percentage increase are the same. At ascending of CM machining speed percentage increment the percentage increments in the AE signals amplitude average level and its standard deviations have a linear nature of increasing. The percentage increment of the AE signals amplitudes average level dispersions increase not linearly. Thus both experimental, and theoretical results demonstrate, that the most sensitive AE statistical amplitude parameter to CM machining speed increasing is the AE signals amplitude average level dispersion. The percentage increment) of AE signals amplitude average level dispersion advances a percentage increment of AE signals amplitude average level and its standard deviation.

VI. CONCLUSION

The experimental and theoretical outcomes of influencing CM machining speed on AE signals statistical amplitude parameters regularity change are reviewed. The experimental AE statistical amplitude parameters regularity changes at ascending CM machining speed are obtained. It is determined that the regularities of ascending registered AE signal amplitudes average level and its standard deviation with increasing CM machining speed are well described by linear functions. At the same time, regularity of ascending AE signal amplitude average level dispersion are well described by an exponential function. The statistical parameters of approximating functions at data processing are obtained. The calculations with definition of experimental AE signals statistical amplitude parameters sensitivity to alteration of CM machining speed are conducted. It is shown, that the percentage increment of AE signals amplitude average level dispersion advances a percentage increment of AE signals amplitude average level and its standard deviation. The experimental and theoretical regularities of AE signals statistical amplitude parameters change at CM machining speed increasing are compared. It is shown that the experimental and theoretical regularities are similar and have a good agreement with each other

The obtained results can be used for optimization of CM machining technological processes, as well as in the development of methods for monitoring and controlling their parameters. In further investigations, it is of interest to investigate the experimental AE signals energy parameters at change of CM machining parameters.

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С. Ф. Філоненко, О. В. Заріцький. Вплив швидкості механічної обробки композиту на експериментальні закономірності зміни амплітудних параметрів акустичної емісії

Розглянуто експериментальні закономірності зміни амплітудних параметрів акустичної емісії при зростанні швидкості механічної обробки композиційного матеріалу. Визначено, що зростання середнього рівня амплітуди сигналу акустичної емісії і його стандартного відхилення описуються лінійними функціями. Закономірність зміни дисперсії середнього рівня амплітуди сигналу акустичної емісії описується степеневою функцією. Визначено чутливість амплітудних параметрів акустичної емісії до зміни швидкості механічної обробки композиційного матеріалу. Показано, що процентний приріст дисперсії середнього рівня амплітуди сигналів акустичної емісії випереджає процентний приріст середнього рівня амплітуди і його стандартного відхилення. Показано, що експериментальні і теоретичні закономірності зміни статистичних амплітудних параметрів сигналів акустичної емісії при зростанні швидкості механічної обробки композиційного матеріалу добре узгоджуються один з одним.

Ключові слова: акустична емісія; композиційний матеріал; сигнал; амплітуда; механічна обробка; управління; статистичні характеристики.

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С. Ф. Филоненко, О.В. Зарицкий. Влияние скорости механической обработки композита на экспериментальные закономерности изменения амплитудных параметров акустической эмиссии

Рассмотрены экспериментальные закономерности изменения амплитудных параметров акустической эмиссии при возрастании скорости механической обработки композиционного материала. Определено, что возрастание среднего уровня амплитуды сигнала акустической эмиссии и его стандартного отклонения описываются линейными функциями. Закономерность изменения дисперсии среднего уровня амплитуды сигнала акустической

эмиссии описывается степенной функцией. Определена чувствительность амплитудных параметров акустической эмиссии к изменению скорости механической обработки композиционного материала. Показано, что процентный прирост дисперсии среднего уровня амплитуды сигналов акустической эмиссии опережает процентный прирост среднего уровня амплитуды и его стандартного отклонения. Показано, что экспериментальные и теоретические закономерности изменения статистических амплитудных параметров сигналов акустической эмиссии при возрастании скорости механической обработки композиционного материала имеют хорошее согласование друг с другом.
Ключевые слова: акустическая эмиссия; композиционный материал; сигнал; амплитуда; механическая обработка; управление; статистические характеристики.

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