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Sergii Filonenko

ACOUSTIC EMISSION AT TREATING TOOL WEAR WITH A NOT CONTROLLED CUTTING DEPTH

National Aviation University
Kosmonavta Komarova avenue 1, 03680, Kyiv, Ukraine
E-mail: fils0101@gmail.com

Abstract

Purpose: *The aim of this article is to research of acoustic emission at composite material machining with not controlled cutting depth and cutting tool from composite material wear.* ***Methods:*** *In the basis of researches lies the simulation acoustic radiation, which appears at destruction of treated composite material surface layer and treating tool wear. The case of prevailing treated composite material mechanical destruction surface layer was esteemed, and tool wear descends without change of cutting depth. The statistical processing of acoustic emission amplitude parameters for want and originating treating composite material wear was conducted. The analysis of acoustic emission amplitude parameters legitimacies change, and as their sensitivity to treating composite material wear at not controlled machining depth was conducted.* ***Results:*** *Is determined, that the ascending of treating composite material wear is accompanied by decreasing of acoustic emission statistical amplitude parameters - amplitude average level, its standard deviation and dispersion. Are obtained of acoustic emission amplitude parameters regularity decreasing at increasing of treating composite material wears. The acoustic emission amplitude parameters percentage decreasing at ascending of treating composite material wear, in relation to their values without tool wear is determined. It is shown, that the decreasing of acoustic emission amplitude average level dispersion advances decreasing of amplitude average level and its standard deviation.* ***Discussion:*** *The simulation of acoustic radiation at prevailing mechanical destruction treated composite material surface layer with a not controlled cutting depth and treating composite material wear is conducted. It is shown, that the ascending of tool wear results in decreasing acoustic radiation statistical amplitude parameters. Is determined, that decreasing of acoustic emission signals amplitude average level dispersion advances decreasing of amplitude average level and its standard deviation. The decreasing of acoustic radiation amplitude average level and its spread values is conditioned by the different contribution of acoustic emission signals components, which appears at treated material destruction and treating composite material wear. Apparently, that at decreasing of treated composite material area destruction the arising signals amplitude parameters decreasing advances ascending of signals amplitude parameters, which appear at increase of treating composite material wear. The outcomes of the conducted researches can be used at mining of cutting tool condition verification methods and control of technological process machining parameters. These methods are of interest in the robotic technological processes, the monitoring and control by which one is possible for conducting through neuronal networks.*

Keywords: Acoustic emission; amplitude; composite material; machining; statistical characteristics; wear.

1. Introduction

The conventional methods of testing's composite materials (CM) machining processes allow to conduct measurements and analysis of cutting forces, temperature, chattering parameters and other characteristics. The researches are directed on optimization the technological processes and mining the methods of their control and monitoring. One of the relevant directions is the cutting tool state estimation.

The conventional methods have a low sensitivity to internal processes descending in treated and treating materials at different levels. It reduces veracity the control and monitoring of technological processes for obtaining the items given quality.

The method of acoustic emission (AE) falls into not to conventional methods. The outcomes of researches demonstrate a sharp response the method to change interplay conditions of treated and treating materials. However advantage of AE method result to the problem registered information interpretation. The problem is aggravated by influencing on AE the machining CM technological parameters, and as treated and treating materials properties. It complicates looking up the legitimacies of AE parameters change for mining the methods verification and monitoring of technological processes.

The solution this problem is possible on the basis of acoustic radiation analytical investigations at CM machining. The models and simulation of AE radiation processes, with allowance of different factors operating, are the basis in definition of acoustic radiation parameters legitimacies change, and, as a consequent, basis in mining the methods verification and monitoring of CM machining technological processes. One of the influential factors is the treating tool wear. Analysis of its influencing on acoustic radiation parameter, unconditionally, introduces scientific and practical concern.

2. Analysis of the latest research and publications

The AE method will widely be used for research of CM machining processes and mining the methods of their control and monitoring. The special value such researches have at automation CM machining processes and monitoring of cutting tool status with neural networks usage.

At researches of AE, that registered during CM machining, is carried out processing mean or root mean square (RMS) AE signals amplitudes, stored RMS AE amplitudes, low frequency and high frequency components in spectra AE signals, statistical amplitude characteristics AE signals, amplitude and power AE signal distributions and other parameters [1-4]. The parameters of AE signals analyze in interconnection with parameters of CM machining technological processes, and as with cutting tool wear.

The outcomes of the conducted researches demonstrate composite nature of acoustic radiation at CM machining. However influencing of treating tool wear or damage on AE is discordant. In articles [5, 6] is shown, that at originating wear or damage of the treating tool there is ascending amplitude or RMS amplitude of AE signals. In article [7] is marked, that at originating tool wear there is ascending average value of AE signal amplitude, and at further tool wear increase AE signal amplitude average value decreases. The decreasing of AE signals amplitude average level, its standard deviation and amplitudes distribution coefficient at increase of treating tool wear is shown in article [3]. However connection of AE amplitude parameters with the treating tool wear has composite and not steady nature. Thus is marked, that to ascending of wear there is decreasing the main carrier frequency amplitude in a spectrum of AE registered signals. In articles [8, 9] is shown, that wear or damage of the treating tool result in decreasing of AE signals RMS amplitudes and value of their deviation. Thus ascending speed of amplitudes low frequency and high frequency components change in spectra of AE signals is watched. In article [4] is marked, that at ascending of treating tool wear there is decreasing *b*-parameter, describing β-distribution of AE signals amplitudes. At the same time, in article [1] is shown, that ascending of tool wear results in sharp ascending of AE signals stored amplitude.

The analytical investigations of AE amplitude parameters at cutting tool wear and controlled cutting depth are conducted in article [10]. The model of AE resultant signal is reviewed, in the basis by which one lays the formation of AE signals U_j and U_i at destruction, accordingly, elementary areas treated CM and treating CM wear

$$U_j(t) = u_0 t\alpha v_0 e^{r\alpha t} e^{-\frac{v_0}{r\alpha}(e^{r\alpha t}-1)}, \quad (1)$$

$$U_i(t) = U_0 V_0 \sigma e^{R\sigma} e^{-V_0 \int_{t_0}^{t} e^{R\sigma} dt}, \quad (2)$$

where u_0 - the maximum elastic displacement at instantaneous destruction of the given treated CM area consisting from N_0 single elements; α – the loading speed; v_0, r - constant, determining properties of treated CM; U_0 – maximum elastic displacement at instantaneous destruction of the given treating CM area consisting from N_1 single elements; V_0, R – constants, dependent on the treating CM characteristics; $\sigma = \alpha t(1-\alpha t)(1-g\sqrt{\alpha t}) - \alpha t_0(1-\alpha t_0)(1-g\sqrt{\alpha t_0})$;

t, t_0 – running time and time the beginning of CM elements destruction; g – coefficient, dependent on the geometrical sizes of CM elements.

Is conducted the simulation of AE signals, reshaped at CM machining with controlled cutting depth, for want of wear and with wear of the treating tool. It is shown, that the increase of treating tool wear and controlled cutting depth results in increasing of all AE resultant signal amplitude parameters (amplitude average level, amplitude average level standard deviation and amplitude average level dispersion). Thus with increasing of treating CM wear the increase of AE signal amplitude average level advances increase of amplitude average level standard deviation and amplitude average level dispersion.

In the actual CM machining technological processes the cutting depth is constant (not controlled). For a case of not controlled cutting depth, with allowance researches, reviewed in article [10], it is possible to conduct the analysis of influencing treating CM tool wear on the AE signals parameters. Such research introduces scientific and practical concern.

3. Research tasks

The purpose of article is the research of AE at CM machining with a not controlled cutting depth and a cutting tool wear from CM.

For achievement the purpose of article the following problems were put: - to conduct simulation of acoustic radiation at cutting tool from CM wear, arising during CM machining with a not controlled cutting depth; - to conduct statistical processing of AE amplitude parameters for want and wear of treating tool from CM, arising at CM machining with a not controlled cutting depth; - to determine regularity of AE amplitude parameters change at increasing the treating tool from CM wear, arising at CM machining with a not controlled cutting depth.

4. Researches results

For realization researches we shall accept CM machining conditions and conditions of acoustic radiation formation, as well as in article [10]. The acoustic radiation without cutting tool wear is reshaped at sequentially destruction of treated CM elementary areas. The acoustic radiation with cutting tool wear is reshaped at sequentially destruction of treated CM elementary areas and sequentially wears of treating CM elementary areas. In other words, the acoustic radiation is reshaped at the expense of AE signals pulse appearance at weep of two processes - at sequentially destruction of treated CM elementary areas and sequentially wears of treating CM elementary areas.

The resultant AE signal, agrees [10], it is represented by the way

$$U_p(t) = \sum_j U_j(t - t_j) + \sum_i U_i(t - t_i), \quad (3)$$

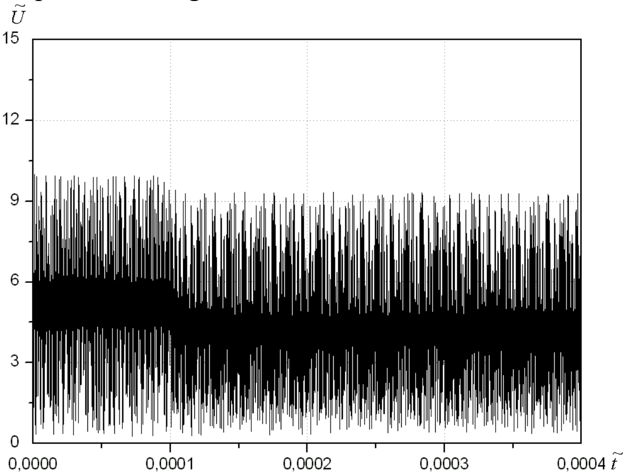
where $t_j = j\Delta t_j \pm \delta_1$ - instants of AE signals U_j appearance at destruction of elementary CM treated area; $t_i = i\Delta t_i \pm \delta_2$ - instants AE signals U_i appearance at wear (destruction) of elementary CM treating area; j - number of CM treated destruction areas or numbers of reshaped AE pulse signals U_j (j = 0,……, n); i - number of CM treating destruction areas or numbers of reshaped AE pulse signals U_i (i = 0,……, m); Δt_j - time interval between the beginning of the subsequent AE pulse signal U_j formation in relation to the previous signal; Δt_i - time interval between the beginning of the subsequent AE pulse signal U_i formation in relation to the previous signal; δ_1 - random component in an instant of each subsequent AE pulse signal U_j appearance; δ_2 - random component in an instant of each subsequent AE pulse signal U_i appearance.

The simulation of AE signals, agrees (3), we shall conduct under condition of absence and availability of treating tool wear in relative units. At simulation we shall consider, that treating tool wearing appear in some time t_0. As we shall consider, that the cutting depth is not controlled, i.e. increase of wear (CM treating destruction area) results in proportional decreasing of CM treated destruction area. The parameters u_0 and U_0 are proportional to the treated and treating CM elementary destruction areas (are proportional to quantity of N_0 and N_1 destruction elements). For want of treating tool wear the values of parameters u_0 and U_0 we shall accept equal: $\widetilde{u}_0$=1, $\widetilde{U}_0$=0. At appearance of treating CM wear in the moment of time t_0 values of parameters u_0 and U_0 we shall accept equal: $\widetilde{u}_0$=0,9, $\widetilde{U}_0$=0,1; $\widetilde{u}_0$=0,8, $\widetilde{U}_0$=0,2; $\widetilde{u}_0$=0,7, $\widetilde{U}_0$=0,3; $\widetilde{u}_0$=0,6, $\widetilde{U}_0$=0,4.

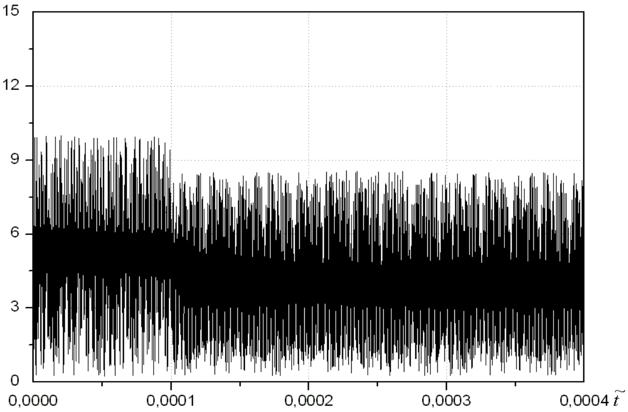
For realization of simulation all parameters, which one enter in expressions (1), (2) and (3), we shall put to non-dimensional values, and their values we shall accept same as well as in article [10]: $\tilde{\upsilon}_0$ = 1000000; $\tilde{r}$ = 10000; $\tilde{V}_0$=1000000; $\tilde{R}$=14000; $\tilde{\alpha}$=10; $\tilde{t}_0$=0,0001; $\tilde{g}$=0,1; $\tilde{\sigma}_0$=0,0009958408846174917; $\tilde{\Delta t}_j$=0,0000015; $\tilde{\Delta t}_i$=0,0000015. Initial values of parameters $\tilde{\delta}_1$ and $\tilde{\delta}_2$ we shall change in range of sizes, accordingly, from 0 up to 0,0000049 and from 0 up to 0,0000049 arbitrarily.

At simulation the calculations 5000 values of AE signal amplitudes for each pair values of parameters u_0 and U_0 were conducted. According to the conducted calculations for adopted conditions of simulation, in a fig. 1 the relations of AE signals amplitude change in time in normalized units are shown.

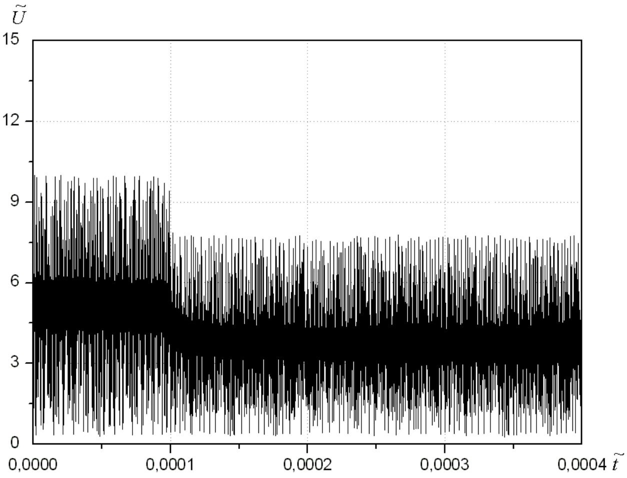
The conducted simulation has shown (fig. 1) that the CM treating wearing appearance and increase for a case of not controlled cutting depth not influences of acoustic radiation nature. The increase of treating tool wear results to decreasing of AE signals amplitude average level and value its deviation.



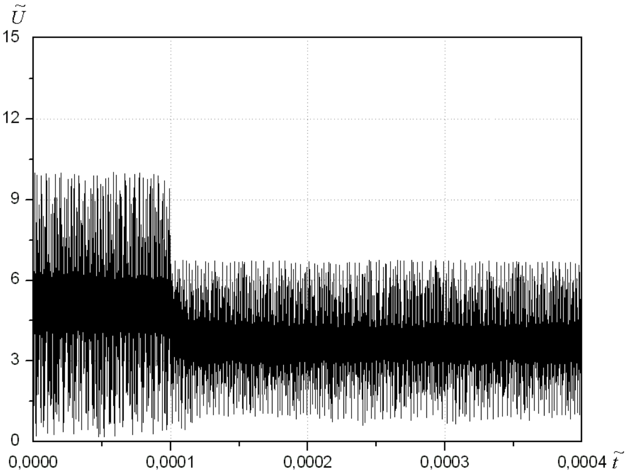
a



b



c



d

Fig. 1 - Relations of AE signals amplitudes change in relative units in time at CM machining with treating tool from CM wear. Time periods: 0 … .0,0001 - absence of tool wear; 0,0001 ….. 0,0004 - availability of tool wear. The values of parameters $\tilde{u}_0$ and $\tilde{U}_0$: on a time period 0….0,0001 - $\tilde{u}_0$=1, $\tilde{U}_0$=0; on a time period 0,0001…..0,0004 - *a* - $\tilde{u}_0$=0,9, $\tilde{U}_0$=0,1; *b* - $\tilde{u}_0$=0,8, $\tilde{U}_0$=0,2; *c* - $\tilde{u}_0$=0,7, $\tilde{U}_0$=0,3; *d* - $\tilde{u}_0$=0,6, $\tilde{U}_0$=0,4

As have shown outcomes data processing for want of treating tool wear AE signal amplitude average level ($\overline{\tilde{U}}$), its standard deviation ($s_{\tilde{\tilde{U}}}$) and dispersion ($s^2_{\tilde{\tilde{U}}}$) in relative units make: $\overline{\tilde{U}}$ =5,04126; $s_{\tilde{\tilde{U}}}$=2,49876; $s^2_{\tilde{\tilde{U}}}$=6,2438. At appearance of treating tool wearing, the value makes which one 0,1, there is decreasing of AE signal amplitude average level ($\overline{\tilde{U}}$), its standard deviation ($s_{\tilde{\tilde{U}}}$) and dispersion ($s^2_{\tilde{\tilde{U}}}$) in relation to their values without tool wear, accordingly: in 1,17825 times, in 1,09083 times and in 1,18991 times. The increase of treating tool wearing up to 0,2 (in 2 times) results in decreasing of AE signal amplitude average level ($\tilde{\tilde{U}}$), its standard deviation ($s_{\tilde{\tilde{U}}}$) and dispersion ($s^2_{\tilde{\tilde{U}}}$) in relation to their values without tool wear, accordingly: in 1,25704 times, in 1,13627 times and in 1,29111 times. As have shown outcomes data processing at increasing tool wear up to 0,3 (in 3 times) the values of AE signal amplitude parameters $\tilde{\tilde{U}}$, $s_{\tilde{\tilde{U}}}$ and $s^2_{\tilde{\tilde{U}}}$ decrease, accordingly: in 1,32833 times; in 1,36966 times and in 1,87598 times. At increasing of tool wear up to 0,4 (in 4 times) the values of AE signals amplitude parameters $\tilde{\tilde{U}}$, $s_{\tilde{\tilde{U}}}$ and $s^2_{\tilde{\tilde{U}}}$ decrease, accordingly: in 1,3633 times, in 1,8275 times and in 3,33977 times.

The outcomes statistical data processing by the way of relations of AE signals amplitude parameters change at treating tool wear increasing and their percentage decreasing, in relation to AE signals parameters without tool wear, are shown in fig. 2.

From fig. 2, *a* it is visible, that increasing of CM treating tool wear results to not a scaling down statistical AE signals amplitude parameters. With increasing of tool wear decreasing of AE signals amplitude average level speed change is watched. At the some time, AE signals amplitude average level standard deviation speed change and AE signals amplitude average level dispersions speed change are augmented. Thus the percentage decreasing of AE signals amplitude average level standard deviation advances percentage decreasing of AE signals amplitude average level (fig. 2, *b*).

At the same time, the percentage decreasing of AE signals amplitude average level dispersion advances percentage decreasing of AE signals amplitude average level and its standard deviation (fig. 2, *b*).

The outcomes of the conducted researches demonstrate, that at CM machining with a not controlled cutting depth the originating of treating tool wear from CM does not influence on acoustic radiation nature. However is watched decreasing of AE signal amplitude average level and value of its deviation. The obtained outcomes will be agreed experimental data by the obtained different writers [8, 9]. The processing of outcomes simulation has shown that at increasing tool wear all statistical AE amplitude parameters decrease. Thus the decreasing of AE signals amplitude average level dispersion advances decreasing of AE signals amplitude average level its standard deviation. So, at increase of treating tool wear in 2 times percentage decreasing of AE signals amplitude average level, its

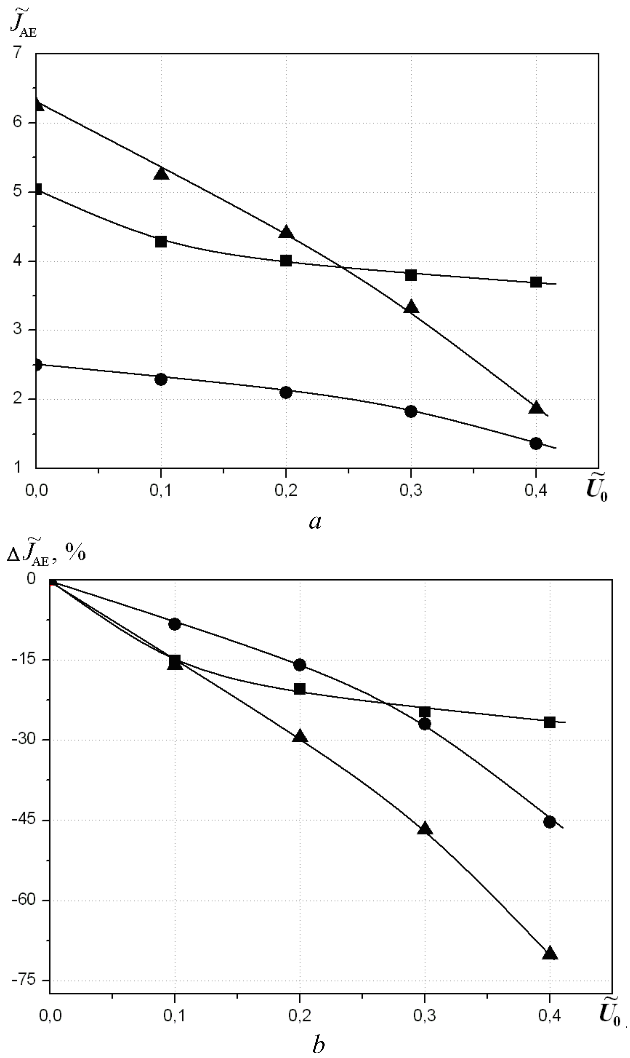


Fig. 2 - The graphs of AE signals amplitude parameters change (*a*) and their percentage decreasing (*b*) at CM machining with a not controlled cutting depth depending on treating tool from CM wear $\tilde{U}_0$: ■ - AE signals amplitude average level ($\tilde{\tilde{U}}$); ● - standard deviation ($s_{\tilde{\tilde{U}}}$) of AE signals amplitude average level; ▲ - dispersion ($s^2_{\tilde{\tilde{U}}}$) of AE signals amplitude average level

standard deviation and dispersions, accordingly, make: 20,448 %, 15,995 % and 29,431 %. At increase of treating tool wear in 4 times percentage decreasing of AE signals amplitude average level, its standard deviation and the dispersions, accordingly, already make: 26,649 %, 45,281 % and 70,059 %.

The decreasing of AE signal amplitude average level and value of its deviation is conditioned by the different contribution of AE signals components from CM treated destruction and treating wear in resultant acoustic radiation. Apparently, that dip of AE signals amplitude parameters at decreasing the CM treated destruction area advances increasing of AE signals amplitude parameters at increase of CM treating wear.

6. Conclusions

One of the tasks in a problem maintenance the given quality items from CM at their machining is the control and monitoring a cutting tool condition. For the solution a problem the control and monitoring of cutting tool condition usage AE method is possible.

The simulation of acoustic radiation at cutting tool wear from a CM, which one arises during CM machining with a not controlled cutting depth is conducted. The statistical processing of outcomes simulation with definition the AE signal amplitude average level, its standard deviation and dispersion values for want and availability treating tool wear from CM and not controlled cutting depth is made. AE signals amplitude parameters regularity change at increase of treating tool wear, for a case of not controlled cutting depth, are obtained. The relations of AE signals amplitude parameters percentage decreasing at increase of treating tool wear in relation to their values for want of wear are determined. It is shown, that at increase of tool wear decreasing of AE signals amplitude average level dispersion advances decreasing AE signals amplitude average level and value of its standard deviation.

The outcomes of conducted researches can be used at mining the methods verification cutting tool condition and control the CM machining parameters. These methods are of interest in the robotic technological processes, the monitoring and control by which one is possible for conducting through neuronal networks. It is necessary to conduct further AE researches, under a not controlled cutting depth condition, with the analysis of influencing cutting tool wearing on AE signals energy parameters.

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С.Ф. Філоненко

Акустична емісія при зносі обробного інструменту з не керованою глибиною різання

Національний авіаційний університет, просп. Космонавта Комарова, 1, Київ, Україна, 03680
E-mail: fils0101@gmail.com

Мета: Метою роботи є дослідження акустичної емісії при механічній обробці композиційного матеріалу з не керованою глибиною різання і зносі ріжучого інструменту з композиційного матеріалу. **Методи дослідження:** В основі досліджень лежить моделювання акустичного випромінювання, яку виникає при руйнуванні поверхневого прошарку оброблюваного композиційного матеріалу і зносі обробного інструменту. Розглядався випадок переважного механічного руйнування поверхневого прошарку оброблюваного композиційного матеріалу, а знос інструменту відбувається без зміни глибини різання. Була проведена статистична обробка амплітудних параметрів акустичної емісії при відсутності і виникненні зносу обробного композиційного матеріалу. Був проведений аналіз закономірностей зміни амплітудних параметрів акустичної емісії, а також їх чутливості до зносу обробного композиційного матеріалу при не керованій глибині механічної обробки. **Результати:** Визначено, що зростання зносу обробного композиційного матеріалу супроводжується зменшенням статистичних амплітудних параметрів акустичної емісії – середнього рівня амплітуди, його стандартного відхилення та дисперсії. Отримано закономірності зменшення амплітудних параметрів акустичної емісії при зростанні зносу обробного композиційного матеріалу. Визначено процентне зменшення амплітудних параметрів акустичної емісії при зростанні зносу обробного композиційного матеріалу, по відношенню до їх значень без зносу інструменту. Показано, що зменшення дисперсії середнього рівня амплітуди акустичної емісії випереджає зменшення середнього рівня амплітуди и його стандартного відхилення. **Обговорення:** Проведено моделювання акустичного випромінювання при переважному механічному руйнуванні поверхневого прошарку оброблюваного композиційного матеріалу з не керованою глибиною різання і зносі обробного композиційного матеріалу. Показано, що зростання зносу інструменту приводить до зменшення статистичних амплітудних параметрів акустичного випромінювання. Визначено, що зменшення дисперсії середнього рівня амплітуди сигналів акустичної емісії випереджає зменшення середнього рівня амплітуди і його стандартного відхилення. Зменшення середнього рівня амплітуди акустичного випромінювання і величини його розкиду обумовлено різним вкладом складових сигналів акустичної емісії, які виникають при руйнуванні оброблюваного і зносі обробного композиційних матеріалів. Очевидно, що при зменшенні площі руйнування оброблюваного композиційного матеріалу зменшення амплітудних параметрів виникаючих сигналів випереджає зростання амплітудних параметрів сигналів, які виникають при зростанні зносу обробного композиційного матеріалу. Результати проведених досліджень можуть бути використані при розробці методів контролю стану ріжучого інструменту і управлінні параметрами технологічного процесу механічної обробки. Дані методи представляють інтерес в роботизованих технологічних процесах, контроль і управління якими можливо проводити через нейронні мережі.

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

С.Ф. Филоненко

Акустическая эмиссия при износе обрабатывающего инструмента с не управляемой глубиной резания

Национальный авиационный университет, просп. Космонавта Комарова, 1, Киев, Украина, 03680
E-mail: fils0101@gmail.com

Цель: Целью работы является исследование акустической эмиссии при механической обработке композиционного материала с не управляемой глубиной резания и износе режущего инструмента из композиционного материала. **Методы исследования:** В основе исследований лежит моделирование акустического излучения, которое возникает при разрушении поверхностного слоя обрабатываемого композиционного материала и износе обрабатывающего инструмента. Рассматривался случай преобладающего механического разрушения поверхностного слоя обрабатываемого композиционного материала, а износ инструмента происходит без изменения глубины резания. Была проведена статистическая обработка амплитудных параметров акустической эмиссии при отсутствии и возникновении износа обрабатывающего композиционного материала. Был проведен анализ закономерностей изменения амплитудных параметров акустической эмиссии, а так же их чувствительности к износу обрабатывающего композиционного материала при не управляемой глубине механической обработки. **Результаты:** Определено, что возрастание износа обрабатывающего композиционного материала сопровождается уменьшением статистических амплитудных параметров акустической эмиссии – среднего уровня амплитуды, его стандартного отклонения и дисперсии. Получены закономерности уменьшения амплитудных параметров акустической эмиссии при возрастании износа обрабатывающего композиционного материала. Определено процентное уменьшение амплитудных параметров акустической эмиссии при возрастании износа обрабатывающего композиционного материала, по отношению к их значениям без износа инструмента. Показано, что уменьшение дисперсии среднего уровня амплитуды акустической эмиссии опережает уменьшение среднего уровня амплитуды и его стандартного отклонения. **Обсуждение:** Проведено моделирование акустического излучения при преобладающем механическом разрушении поверхностного слоя обрабатываемого композиционного материала с не управляемой глубиной резания и износе обрабатывающего композиционного материала. Показано, что возрастание износа инструмента приводит к уменьшению статистических амплитудных параметров акустического излучения. Определено, что уменьшение дисперсии среднего уровня амплитуды сигналов акустической эмиссии опережает уменьшение среднего уровня амплитуды и его стандартного отклонения. Уменьшение среднего уровня амплитуды акустического излучения и величины его разброса обусловлено различным вкладом составляющих сигналов акустической эмиссии, которые появляются при разрушении обрабатываемого и износе обрабатывающего композиционного материалов. Очевидно, что при уменьшении площади разрушения обрабатываемого композиционного материала уменьшение амплитудных параметров возникающих сигналов опережает возрастание амплитудных параметров сигналов, которые возникают при увеличении износа обрабатывающего композиционного материала. Результаты проведенных исследований могут использоваться при разработке методов контроля состояния режущего инструмента и управления параметрами технологического процесса механической обработки. Данные методы представляют интерес в роботизированных технологических процессах, контроль и управление которыми возможно проводить через нейронные сети.

Ключевые слова: акустическая эмиссия; амплитуда; износ; композиционный материал; механическая обработка; статистические характеристики.

Filonenko Sergii. Doctor of Engineering. Professor.
Director of the Institute of Information-Diagnostic Systems, National Aviation University, Kyiv, Ukraine.
Education: Kyiv Polytechnic Institute, Kyiv, Ukraine (1977).
Research area: diagnostics of technological processes and objects, automatic diagnostic systems.
Publications: 285.
E-mail: fils0101@gmail.com