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THE CONTROL OF INCIPIENT STATE TREATING TOOL WEAR WITH USAGE OF ACOUSTIC EMISSION

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Abstract

Purpose: *The aim of this article is the experimental research of acoustic emission at composite material machining with the analysis of influencing treating tool wear from composite material on registered signals parameters.* ***Methods:*** *In the basis of researches lies the processing and analysis of interconnection experimental acoustic emission signals parameter, which one appear at composite material machining, with treating tool wear. The acoustic emission at initial and final stage of composite material machining are esteemed. The statistical processing of acoustic emission amplitude parameters on these stages was conducted. The statistical data processing with the analysis regularity change of acoustic emission signals amplitudes distribution kurtosis is conducted.* ***Results:*** *Is determined, that the increase of composite material machining time does not result in change of acoustic radiation nature. The registered acoustic emission signals are continuous signals. Is established, that at composite material machining final stage is watched decreasing of acoustic emission signal amplitude average level and value of its deviation. Is determined, that the gradual or instantaneous increase of treating tool wear results in its destruction and sharp decreasing of acoustic emission signal amplitude. The regularity change of acoustic emission signals amplitudes distribution kurtosis at all stages of composite material machining is established.* ***Discussion:*** *The analysis of acoustic emission statistical amplitude parameters change at initial and final stage composite material machining is conducted. Decreasing of acoustic emission statistical amplitude parameters at final stage of machining is shown, that is conditioned by treating tool wear. It is shown, that originating and development of treating tool wearing up to an instant of its damage results in minor decreasing of acoustic emission signal amplitude average level. At the same, at early stage, which one will precede to tool damage, there is a discontinuous of acoustic emission signals amplitudes distribution kurtosis change from stable positive value up to negative value. At the moment of tool disastrous damage the nature of acoustic emission signals amplitudes distribution kurtosis change varies on inverse. Such change of acoustic emission parameters, apparently, is conditioned by originating the processes leading to tool destruction, and, as a consequent, change of treating and treated composite materials conditions interplay. The obtained outcomes have shown that the processing and analysis of regularity of acoustic emission signals amplitudes distribution kurtosis change can be utilized for control of composite materials technological process machining. Thus it is possible to determine and control the moment of processes originating incipient state, which one conduct to destruction of the treating tool.*

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

1. Introduction

By one of directions researches of composite materials machining technological processes is a treating tool condition monitoring. At researches the different methods will be used. By one of such methods is the method of acoustic emission (AE). The researches encompass all operations of machining – turning, milling, drilling, grinding and other.

The conducted researches demonstrate a sharp response of AE method to the processes of treated and treating CM interplay. Thus during CM machining is watched continuous change of registered acoustic radiation parameters. At the same time, as demonstrate researches, on acoustic emission is influenced of large number factors. Such factors are the technological factors (CM machining technological process parameters) and physical-mechanical characteristics treated and treating CM.

The AE method has short-term lag to the processes descending in materials at their deformation and destruction. It allows to receive the large amounts information about flowing past processes. However availability of the influential factors results in a problem of interpretation the registered information. This problem to the full concerns and to treating tool condition monitoring, i.e. its wear and damage. The analytical AE investigations at treating CM wearing demonstrate change of acoustic radiation parameters. However they allow describing the fact of availability wear with prescribed value.

At the same time, at monitoring and control of CM machining has definition the value of beginning of originating processes, which one conduct to treating CM wear or damage. Unconditionally, that definition of AE parameters, which one allow to determine a beginning of these processes introduces not only scientific, but also practical concern.

2. Analysis of the latest researches and publications

To the usage of AE method in research of materials machine technological processes, switching on and CM, is dedicated a plenty of articles. In articles [1-4] the application of AE method in different machining operations (turning, milling, drilling and other) is shown. Thus the relevant direction of researches is marked, which one is connected with cutting tool condition monitoring. The special value this direction has in the robotic effecting and as at the control of technological processes with usage of neural networks. The conducted researches demonstrate composite nature of acoustic radiation at materials machining. The radiation for the materials with crystalline structure and CM is like. It is continuous and has composite nature of a time history. At processing and analysis of such kind of radiation the different AE parameters be used – spectrum of AE signal or its spectral components in given frequency band, root mean square (RMS) value of amplitude, power spectrum of AE signals, AE signal amplitude average value, statistical parameters of AE signals amplitude distributions, AE signals accumulation and other [4, 5, 6]. The analysis of AE parameters carry out for looking up of their interconnecting with treating tool wear or damage. Thus the activities on creation of discriminatory analysis's of tool condition are carried out [7] for control of machining technological processes. However outcomes of the conducted researches not always will be agreed one another.

In articles [8, 9] is shown, that the originating of damage is accompanied by ascending of cutting forces. Thus there is decreasing of AE registered signal amplitude, and as decreasing the value of its spread. The analysis of the obtained data as demonstrates, that the changes in AE registered signal spectrum are watched. The high frequency and low frequency components in AE registered signal spectrum are decrease. The return nature of AE signals parameters change is marked in articles [10, 11, 12] – the ascending of treating material wear results in ascending of AE registered signal amplitude average level. Relations of AE signal amplitude average level change, as is marked in article [10], can be yardsticks of tool state estimation with usage of neural networks. At the same time, in article [13] the composite nature of AE registered signals parameters change is showed at ascending of treating tool wear. So the ascending of tool wear results in general decreasing of AE signal amplitude, AE signal amplitude average level, its standard deviation and amplitude distribution skewness. Thus the ascending amplitude RMS value and kurtosis is watched. The decreasing of AE power signal distribution skewness with ascending of treating tool wear is shown and in article [14]. However kurtosis has more composite nature of change.

The analytical investigations of acoustic radiation parameters at treating material wear are reviewed in articles [15, 16, 17]. The researches of AE amplitude and energy parameters conducted under conditions of a controlled and not controlled cutting depth. It was supposed, that the acoustic radiation is reshaped at series destruction of treated CM elementary areas and CM treating wear. The acoustic radiation is reshaped by the way sequences of AE pulse signals. The models are obtained and the analysis of outcomes AE resultant signals simulation is conducted, which one has shown following. CN treating wear does not influence of

acoustic radiation nature, which one is continuous. At a controlled cutting depth ascending of CM treating wear results in ascending of AE signals statistical amplitude and energy parameters. The matching of AE signals amplitude and energy parameters has shown, that the ascending of AE signals energy parameters advances ascending their amplitude parameters. Thus most sensing AE parameter is the dispersion of AE resultant signal energy average level. At the same time, if the cutting depth is not controlled, increase of CM treating wear results in decreasing of AE statistical amplitude parameters (amplitude average level, its standard deviation and dispersion). Such results will be agreed with the experimental data that obtained by different writers [8, 9]. The analysis of AE amplitude parameters increment [17] has shown, that with treating CM wear increase the decreasing of AE amplitude average level dispersion advances decreasing of AE amplitude average level and value of its spread.

The obtained outcomes demonstrate a general tendency of AE signals parameters change at treating tool wear. However it is necessary to determine began of originating processes, which one conduct to tool wear or damage. The solution of this problem is the basis for mining of treating tool condition verification methods and control of CM machining technological processes.

3. Research tasks

The aim of this article is the experimental research of acoustic emission at composite material machining with the analysis of influencing treating tool wear from composite material on registered signals parameters.

For achievement the purpose of article the following problems were put: – to conduct experimental researches of CM machining with the recording of AE signal; – to conduct statistical data processing with the analysis of AE signals parameters change at initial and final stages of machining process (for want and availability of treating CM wear); – to conduct statistical data processing with the analysis of AE signals parameters legitimacies change on initial stages originating of treating tool wear.

4. Research results

The researches of AE signals conducted at initial and final stages of CM machining on the basis of aluminum. At realization of CM machining the technological parameters were constants, the values made which one: bar rotation speed – 440 r/m and 880 r/m; treating tool feed speed – 0,1 mm/r; cutting depth – 0,1 mm. As treating CM have used the laminas from CD10 alloy and coating PCD. The bar machining was conducted on a thread-cutting lathe.

For recording of the AE signal the piezoeceramic sensor made on the basis of piezoceramic ZTS-19 was used. The AE was placed on a tool holder (Fig. 1). The surface of the sensor was lubricated with acoustic-transparent lubrication. The signal, that registered by the AE sensor, strengthened and transmitted in an informational – measuring system (IMS) (Fig.1). In IMS analog signal transformation to a digital code was conducted. With usage of program software the registered signal processing was conducted with formation and preservation of the data in file frames. The secondary processing of file frames with formation the tabular data on AE signals statistical parameters and injection the charts change of parsed parameters was hereinafter conducted. Quantity of measurements for each registered AE signal made $2 \cdot 10^6$. The sensitivity of the signal converter made 2,44 mV per unit bit and sampling rate made 150 kH. Before record of AE signals preliminary processing of bar was conducted, diameter by which one made 71,8 mm.

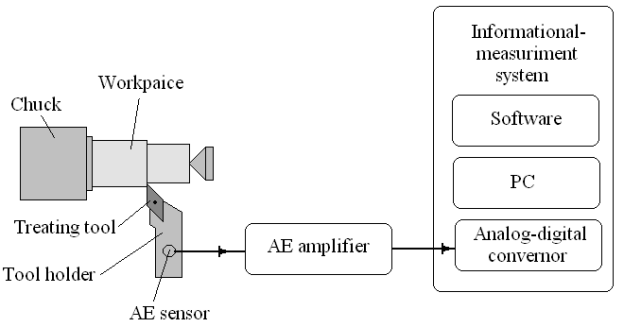
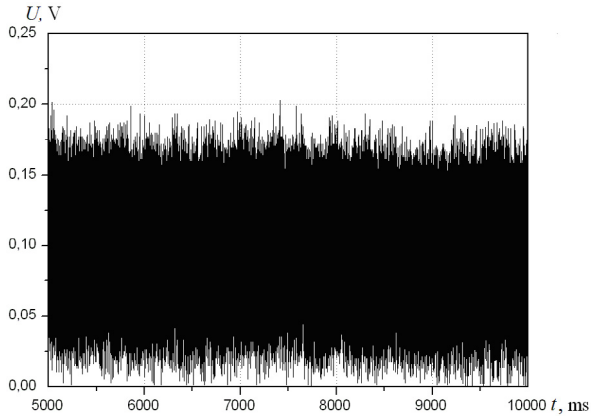


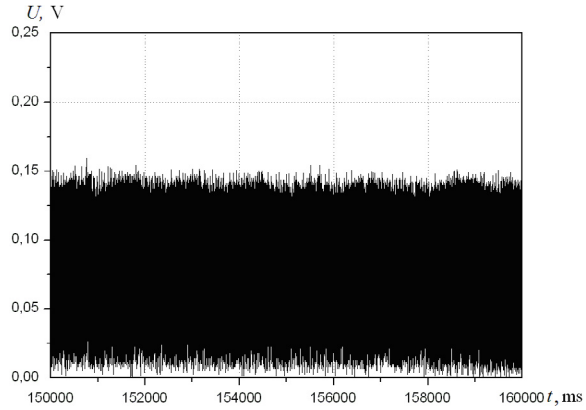
Fig. 1. Frame of experimental installation AE signals research at CM machining

The outcomes of the conducted researches have shown following. The increase of machining time does not result in change of acoustic radiation nature. The registered AE signals are continuous signals. However increase of machine time results in decreasing an amplitude average level and value of its spread. In a Fig.2 the relations of AE signals amplitude change on an incipient state (*a, c*) and final stage (*b, d*) of CM machining for miscellaneous cutting speeds are shown.

As statistical processing has shown, at rotation rate of bar 440 r/m on initial stage of CM machining the AE signal amplitude average level ($\overline{U}$), its standard deviation ($s_{\overline{U}}$) and dispersion ($s^2_{\overline{U}}$), accordingly, are make: 0,113 V; 0,03121 V; 0,000974 V^2. At final stage of CM machine the AE parameters $\overline{U}$, $s_{\overline{U}}$ and $s^2_{\overline{U}}$, accordingly, are make: 0,0912 V; 0,02896 V; 0,000842 V^2. At rotation rate 880 r/m on an initial stage of CM machining the AE signal amplitude average level ($\overline{U}$), its standard deviation ($s_{\overline{U}}$) and dispersion ($s^2_{\overline{U}}$), accordingly,



a



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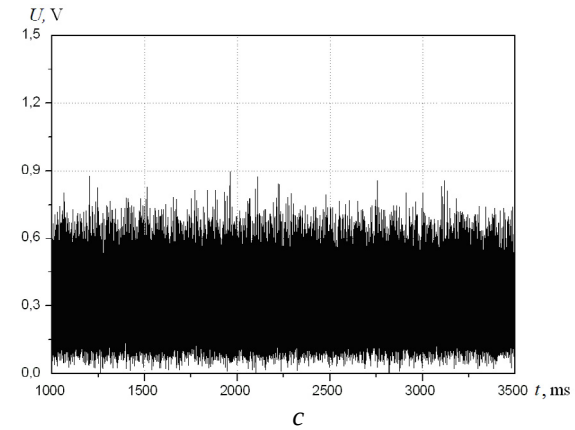
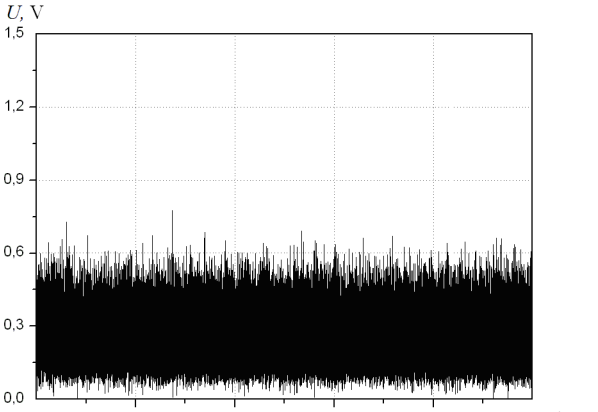


c



d

Fig.2. Pieces of experimental AE signals amplitude change on initial stage (*a, c*) and final stage (*b, d*) of CV machining for miscellaneous cutting speeds. Rotation rate of bar: *a, b* – 440 r/m; *c, d* – 880 r/m

are make: 0,26753 V; 0,08299 V; 0,00689 V^2. At final stage of CM machine the AE parameters $\overline{U}$, $s_{\overline{U}}$ and $s^2_{\overline{U}}$, accordingly, are make: 0,2368 V; 0,0684 V, 0,0046 V^2.

The research of treating tool has shown that at final stage of CM machining is watched of cutting edge wear.

It is necessary to mark, that the decreasing of AE signal amplitude at originating wear descends by a gradual mode to the subsequent stabilization of its parameters. At the same time, the gradual or instantaneous increases of treating tool wear results in its damage or destruction. The given situation is more critical. It's originating results in damage of treated material. Thus, as demonstrate researches, tool damage or destruction is accompanied by sharp decreasing of AE registered signal amplitude (Fig. 3). The point *B* in Fig.3 corresponds to the time moment of treating material destruction.

The statistical data processing on given analysis intervals (2 s) has shown, that up to a point *B* (Fig. 3) the change of AE amplitude average level is not considerably. From point *C* up to point B (Fig. 3) the decreasing of AE amplitude average level makes 0,14 %. At the same time, statistical data processing with definition of AE signals amplitudes distribution kurtosis on time periods 2 s has shown following. On the initial stage of CM machining in the limits of time from 50 s up to 74 s (up to point *C*, Fig. 4) the AE signals amplitudes distribution kurtosis has practically stable positive value (Fig. 4). On a time period from 74 s up to 76 s (began of originating and development the processes of treating material

destruction) the discontinuous of AE signals amplitudes distribution kurtosis change from positive up to negative value is watched. Its discontinuous dip makes 8 %.

Hereinafter the AE signals amplitudes distribution kurtosis has negative value before disastrous destruction of treating tool that corresponds to point *B* in Fig. 3. The transition to disastrous destruction is accompanied by discontinuous ascending of AE signals amplitudes distribution kurtosis from negative to positive value (point *N* in Fig. 4.). The subsequent process of CM machining is accompanied not by large ascending of AE signals amplitudes distribution kurtosis and stabilization of its value. Such stabilization is watched and on AE signals amplitude average level. It is apparently conditioned by stabilization new conditions of CM treated and treating interplay.

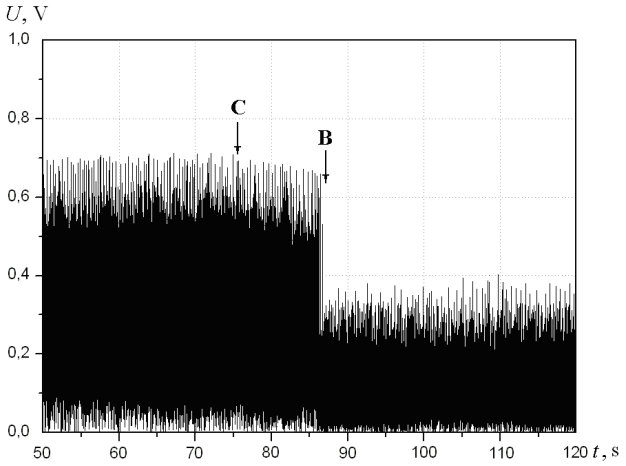


Fig.3. Piece of experimental AE signal at CM machining. Values of the technological parameters: feed rate of tool – 0,1 mm /r; rotation rate of bar – 880 r/m; cutting depth – 0,1 mm

The outcomes of the conducted researches demonstrate, that the processing and analysis of AE signals amplitudes distribution kurtosis regularity change can be used for definition and control the moment of originating incipient state processes, which one conduct to destruction of treating tool. As the data processing, instant of originating these processes, in relation to an instant of disastrous tool destruction demonstrates, is determined on 15,34% earlier.

6. Conclusions

By one of CM machining technological processes directions researches is the control and monitoring of treating tool condition. One of researches methods is the AE method. The experimental researches of AE signals are conducted at CM machining. It is shown, that the increase of CM machining time does not result in acoustic radiation nature change. The registered AE signals are continuous signals. At the same too time, at final stage of CM machining decreasing of AE signal amplitude average level and value of its spread is watched. It is conditioned by originating and development in time of treating tool wear. It is shown, that the gradual or instantaneous increase of treating tool wear results in its destruction and sharp decreasing of AE signal amplitude. The statistical data processing at all stages of CM machining is conducted. It is shown, that up to the moment of originating treating tool damage the decreasing of AE signal amplitude average level does not exceed 0,14 %. At the same time, the regularity of AE signals amplitudes distribution kurtosis change is determined. At early stage, which one will precede to tool damage, there is a discontinuous of AE signals amplitudes distribution kurtosis change from positive stable value up to negative value. At the moment of disastrous tool damage the nature of AE signals amplitudes distribution kurtosis change varies on inverse.

The obtained outcomes have shown, that the processing and analysis of AE signals amplitudes distribution kurtosis regularity change can be used for the control of CM machining technological processes. Thus it is possible to determine and to control the moment of originating incipient state processes, which one conduct to treating tool destruction.

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Контроль початкової стадії зносу обробного інструменту з використанням акустичної емісії

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Мета: Метою роботи є експериментальні дослідження акустичної емісії при механічній обробці композиційного матеріалу з аналізом впливу зносу обробного інструменту з композиційного матеріалу на параметри реєстрованих сигналів. **Методи дослідження:** В основі досліджень лежить обробка та аналіз взаємозв'язку параметрів експериментальних сигналів акустичної емісії, які виникають при механічній обробці композиційного матеріалу, із зносом обробного інструменту. Розглянуто сигнали акустичної емісії на початковому і кінцевому етапах механічної обробки композиційного матеріалу. Була проведена статистична обробка амплітудних параметрів акустичної

емісії на даних етапах. Проведена статистична обробка даних з аналізом закономірності зміни коефіцієнту ексцесу розподілу амплітуд сигналів акустичної емісії. **Результати:** Визначено, що зростання часу механічної обробки композиційного матеріалу не приводить до зміни характеру акустичного випромінювання. Реєстровані сигнали акустичної емісії є неперервними сигналами. Встановлено, що на кінцевій стадії механічної обробки композиційного матеріалу спостерігається зменшення середнього рівня амплітуди сигналу акустичної емісії і величини його розкиду. Визначено, що поступове або миттєве зростання зносу обробного інструменту приводить до його руйнування і різкому зменшенню амплітуди сигналу акустичної емісії. Визначено процентне зменшення середнього рівня сигналу акустичної емісії до моменту виникнення пошкодження обробного інструменту. Встановлено закономірність зміни коефіцієнту ексцесу розподілу амплітуд сигналів акустичної емісії на всіх етапах механічної обробки композиційного матеріалу. **Обговорення:** Проведено аналіз зміни статистичних амплітудних параметрів акустичної емісії на початковому і кінцевому етапах механічної обробки композиційного матеріалу. Показано зменшення статистичних амплітудних параметрів акустичної емісії на кінцевому етапі механічної обробки, що обумовлено зносом обробного інструменту. Показано, що виникнення і розвиток зносу обробного інструменту до моменту часу його пошкодження приводить до незначного зменшення середнього рівня амплітуди сигналу акустичної емісії. У той же час, на ранній стадії, яка передує пошкодженню інструменту, відбувається стрибкоподібна зміна коефіцієнту ексцесу розподілу амплітуд сигналів акустичної емісії від стабільного позитивного значення до негативного значення. В момент катастрофічного пошкодження інструменту характер зміни коефіцієнту ексцесу розподілу амплітуд сигналів акустичної емісії змінюється на протилежний. Така зміна параметрів акустичної емісії, очевидно, обумовлена виникненням процесів,які ведуть до руйнування інструменту, і, як наслідок, зміни умов взаємодії обробного і оброблюваного композиційних матеріалів. Отримані результати показали, що обробка і аналіз закономірності зміни коефіцієнту ексцесу розподілу амплітуд сигналів акустичної емісії може бути використана для управління технологічним процесом механічної обробки композиційного матеріалу. При цьому можливо визначати і контролювати момент виникнення початкової стадії процесів, які ведуть до руйнування обробного інструменту.

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

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Контроль начальной стадии износа обрабатывающего инструмента с использованием акустической эмиссии

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Цель: Целью работы является экспериментальное исследование акустической эмиссии при механической обработке композиционного материала с анализом влияния износа обрабатывающего инструмента из композиционного материала на параметры регистрируемых сигналов. **Методы исследования:** В основе исследований лежит обработка и анализ взаимосвязи параметров экспериментальных сигналов акустической эмиссии, которые возникает при механической обработке композиционного материала, с износом обрабатывающего инструмента. Рассматриваются сигналы акустической эмиссии на начальном и конечном этапе механической обработки композиционного материала. Была проведена статистическая обработка амплитудных параметров акустической эмиссии на данных этапах. Проведена статистическая обработка данных с анализом закономерности изменения коэффициента эксцесса распределения амплитуд сигналов акустической эмиссии. **Результаты:** Определено, что увеличение времени механической обработки КМ не приводит к изменению характера акустического излучения. Регистрируемые сигналы АЭ являются непрерывными сигналами. Установлено, что на конечной стадии механической обработки композиционного материала наблюдается уменьшение среднего уровня амплитуды сигнала АЭ и величины его разброса. Определено, что постепенное или мгновенное увеличение износа обрабатывающего инструмента приводит к его разрушению и резкому уменьшению амплитуды

сигнала АЭ. Определено процентное уменьшение среднего уровня сигнала акустической эмиссии до момента возникновения повреждения обрабатывающего инструмента. Установлена закономерность изменения коэффициент эксцесса распределения амплитуд сигналов акустической эмиссии на всех этапах механической обработки композиционного материала. **Обсуждение:** Проведен анализ изменения статистических амплитудных параметров акустической эмиссии на начальном и конечном этапе механической обработки композиционного материала. Показано уменьшение статистических амплитудных параметров акустической эмиссии на конечном этапе механической обработки, что обусловлено износом обрабатывающего инструмента. Показано, что возникновение и развитие износа обрабатывающего инструмента до момента времени его повреждения приводит к незначительному уменьшению среднего уровня амплитуды сигнала акустической эмиссии. В тоже время, на ранней стадии, которая предшествует повреждению инструмента, происходит скачкообразное изменение коэффициент эксцесса распределения амплитуд сигналов АЭ от стабильного положительного значения до отрицательного значения. В момент катастрофического повреждения инструмента характер изменения коэффициента эксцесса распределения амплитуд сигналов АЭ меняется на противоположный. Такое изменение параметров акустической эмиссии, очевидно, обусловлено возникновением процессов ведущих к разрушению инструмента, и, как следствие, изменением условий взаимодействия обрабатывающего и обрабатываемого композиционных материалов. Полученные результаты показали, что обработка и анализ закономерности изменения коэффициента эксцесса распределения амплитуд сигналов АЭ может быть использована для управления технологическим процессом механической обработки КМ. При этом возможно определять и контролировать момента возникновения начальной стадии процессов, которые ведут к разрушению обрабатывающего инструмента.

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

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