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THE RESEARCH OF THE TEMPERATURE DEPENDENCE AND QUALITY ASSESSMENT OF HOLES DURING THE OSCILLATING DRILLING OF PCM

Bulakh I.A., Globa A.V., Solodkiy V.I.
National Technical University of Ukraine
«Kyiv Polytechnic Institute»

The process of oscillating drilling holes in polymeric composite materials (PCM) was investigated in this paper. Using the group method of data handling (GMDH) the multifactor empirical dependence of drilling process parameters such as the magnitude and the rate of wear, temperature, and geometric parameters of the instrument and the correction coefficients of the model, were obtained. According to the methodology, based on a mathematical method of least squares, was evaluated the quality of received holes (deviation from a circular shape). We measured the temperature of cutting by natural thermocouple and with a laser pyrometer. The results obtained by both methods were compared. The processing of inclined surfaces was investigated.

Keywords: polymer composite materials, oscillating movement of the tool, assessing the quality of holes, the method of least squares, the temperature of cutting zone, inclined surfaces.

Introduction. In today's society there is increasing demand for polymeric composite materials (PCM), used in all industries, and in engineering and aviation the most. This leads to the continuous development of new materials with different characteristics. Therefore, well-known design of tools and cutting modes chosen for metals or PCMs of a particular type are not applicable for new types of materials.

Considering current development of technologies for polymer composite materials processing, and material structure, variety of processes is applied. Drilling holes in the PCM is the most common processing operation.

Slight wear on the front surface caused by small forces is typical for PCM processing. At the same time, wear level on the back is high, due to contact phenomena through a large elastic recovery of the manufacturing surface. To increase instrument stability, it is necessary to reduce wear intensity, depending on the tool material type, tool geometry, it's sharpening diligence and cutting mode.

Modern industries, aerospace in particular, require high reliability of PCM panels fastening. Therefore, it is important to ensure the highest possible precision and quality of holes (H9 – H10). Known tool constructions are unable to provide this level of quality. Holes quality control is also a problem due to PCM products dimensionality. Therefore, task of finding instrument geometry, as well as selection of the optimal cutting mode providing high quality holes without the supervisory methods is an extremely important task.

The level of research. Results of conducted tools research and mathematical modeling are outlined in papers prepared by Globa A., Bulakh I. and Mylokost S. [1-4]. Technique of holes quality evaluation, described in this article, is used to improve results accuracy.

The main part. Vibro-acoustic signal analysis was used to calculate magnitude and rate of tool wear. The vibro-acoustic signal was recorded in the following way (Fig. 1): upon reach of a critical force value (critical load), the avulsion of the remaining material layers from the main material occurs. This phenomenon is accompanied by a vibro-acoustic effect. Vibro-acoustic effect is recorded as a signal by the sensor mounted on the sample. Signal is transmitted from the sensor to amplifier and then to the analog-to-digital converter, where the data is digitized.

For data processing Cool Edit Pro 2 was used. This program allows recording audio multitrack data from a microphone or any sound source (in our case this is the sensor), editing and processing it as a separate file or a group of files, performing mastering and keeping record.

The most serious problem during holes drilling in the PCM is the delamination, which significantly reduces fastening strength and reliability. Standard drilling, causing the separation and appearance of tattered fibers in material is used during PCM processing. Reverse tool movement was used in this research to avoid described defects [2].

The general view of the experimental facility is shown on Fig. 2 and 3.

Processing was carried out changing cutting modes, at different machine spindle speeds, as well as using experimental appliance for reverse tool movement providing bidirectional drilling (Fig. 2, 1)

The essence of the experimental appliance is that it is equipped with the movement recovery mecha-

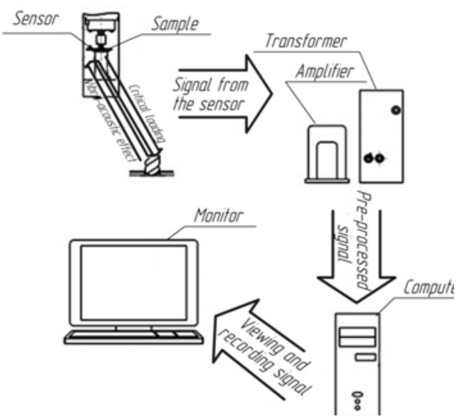


Fig. 1. Scheme of vibro-acoustic signal recording

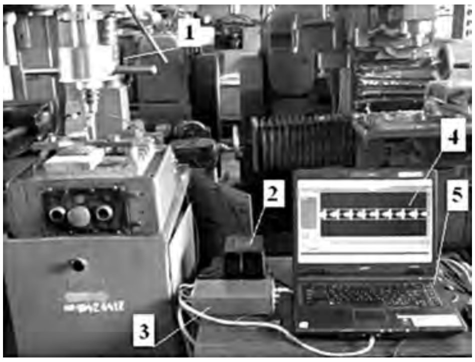


Fig. 2. The experimental appliance

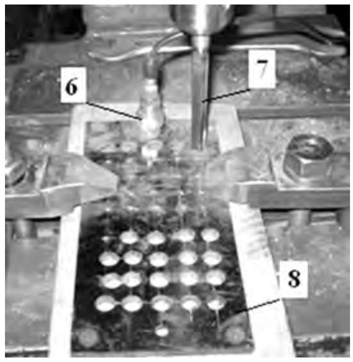


Fig. 3. Element of appliance

1 – device for oscillating vibrations, 2 – Amplifier, 3 – Transformer 4 – View of recorded vibration, 5 – Computer 6 – vibroacoustic sensor, 7 – Drill 8 – The sample of carbon fiber nism for reverse drilling (application for an invention to receive a patent have been filed).

Drill of construction presented on Fig. 3 (7) and Fig. 13 (a) was developed for the experiment. Such construction has not been previously used for the processing holes in PCM. We studied three samples with different tool double entering angles of – 110˚, 120˚, 130˚ (see examples 1, 2 and 3 below respectively). Drill diameter- 8 mm, material – P18, hardness – HRC 60. Such material was chosen because of the necessity to obtain visible tool wear at low series of experiment. Sample of two cutting edges drill (Fig. 13, b) and step drill (Fig. 13, c) was chosen to compare holes quality. Step drill was taken with a double entering angle $2\varphi = 130˚$, based on previous researches of the tool wear and holes quality conducted by analyzing the vibroacoustic signal [3].

For the study composite material, carbon fiber 6 mm cross- reinforcement (with layout 0-90˚), reinforced by organic net was taken. During the drilling machine spindle rotation frequency was changed (from 480 rev/min to 880 rev/min) and experimental appliance 1 was used. This tool is capable of oscillating vibrations exciting which leads to bidirectional drilling, with the rotational speed change according to the frequency of spindle rotation. The appliance creates oscillations that were taken into account during tool wear calculation (due to the recording and subsequent subtraction of idling rigs).

Holes quality. Deviation from roundness

The Fig. 4 and Fig. 5 show view of the holes at the tool entry and exit during processing with different drilling modes.

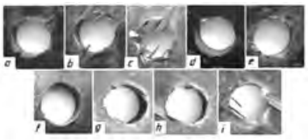


Fig. 4. View of holes at the drill entry

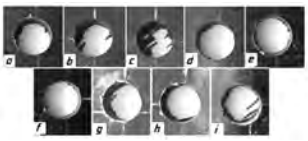


Fig. 5. View of holes at the drill exit

a. sample 1, n = 480 rev/min without device b. sample 2, n = 480 rev/min., without devise; c. Sample 3, n = 480 rev/min., without device ; d. sample 1, n = 480 rev/min., with device, e. Sample 2, n = 480 rev/ min., with device; f. Sample 3 , n = 480 rev/min., with device; g. sample 1, n = 880 rev/min., with device, h. sample 2, n = 880 rev/min., with device; i. Sample 3, n = 880 rev/min., with device

Calculation results of holes deviation from round form are sh own in the diagram (Fig. 6). The diagram shows that for each cutting mode the smallest deviation from roundness is achieved with drill of a different geometry.

At the same time the smallest average deviation from roundness obtained in mode 2 (n = 480 rev/min with the use of drill oscillating motion). It makes more accurate selection of cutting parameters and tool geometry exactly for this cutting mode perspective.

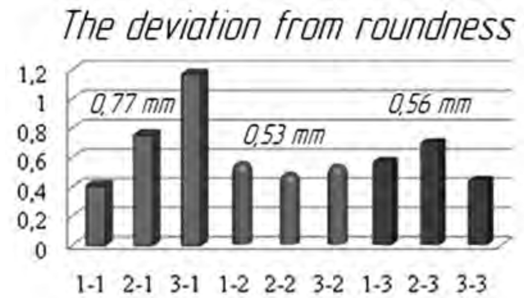


Fig. 6. Deviation from holes roundness

Wear of tool

The Fig. 7 and 8 show dependency between tool wear and path traversed by a drill. Graphics for 3 cutting edges drill and four samples of step drills are presented on Fig. 8. Fig. 7 shows the dependency for three samples of experimental tool.

It was observed that largest wear occurs in the processing mode 1 (no adjustment at a frequency of 480 rev/min). The lowest wear takes place in mode №3, but holes quality in this mode is low.

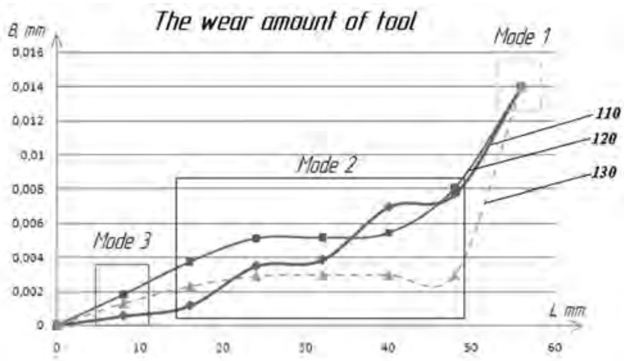


Fig. 7. The results of experimental samples of instrument research

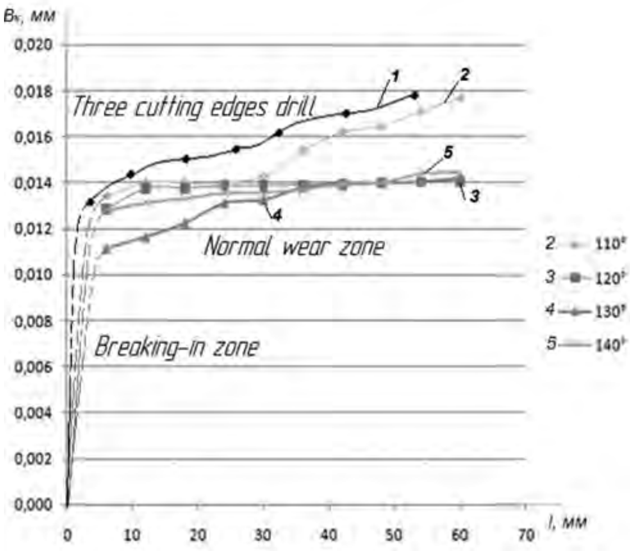


Fig. 8. Graphics obtained after examining 3 cutting edges and step drills

Fig. 9 and 10 show diagrams of wear magnitude and processing time for experimental samples of the instrument in different modes.

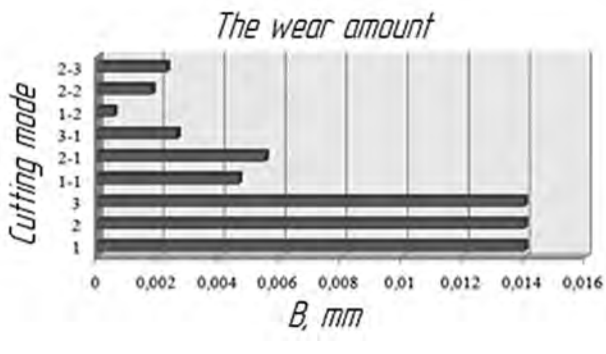


Fig. 9. Diagram of tool wear magnitude

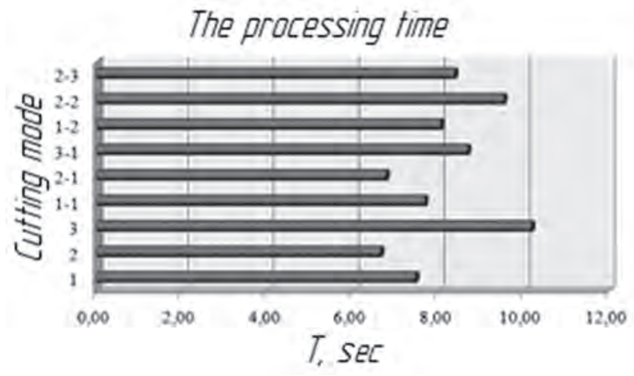


Fig. 10. Diagram of processing time

The fundamental in research of PCM processing is to construct the mathematical models, taking into account process parameters and material properties, which will allow making processing results prediction changing certain process parameters.

Considering high cost of materials and PCM processing peculiarities, it is necessary to perform mathematical modeling of the cutting process to be able to predict processing results. One-factor cutting process model for cutting with step drill is presented in research [1]. To improve prediction accuracy, it is necessary to increase the number of process parameters.

Mathematical model based on the results of the experiment [1]:

$$\boldsymbol{B} = 0{,}4244 \cdot (3{,}410^{-3}+1{,}00308 \cdot (\mathbf{L}{*}0{,}1 \cdot 10^{-3}- \boldsymbol{t}{*}0{,}4 \cdot 10^{-3})+$$
$$+1{,}306 \cdot (9{,}8 \cdot 10^{-3}-\boldsymbol{k}{*}9{,}72 \cdot 10^{3})+0{,}7076 \cdot (21{,}04 \cdot 10^{-3}-$$
$$-\boldsymbol{n}{*}1{,}2 \cdot 10^{-5}-\boldsymbol{f}{*}7{,}564 \cdot 10^{-5}))+ 0{,}577 \cdot ((4{,}4210^{-3}-$$
$$-\boldsymbol{t}{*}0{,}571 \cdot 10^{3}+1{,}015 \cdot (13{,}9 \cdot 10^{-3}-\boldsymbol{k}{*}10{,}1 \cdot 10^{-3}){*}\ 1{,}357 \cdot$$
$$\cdot ((4{,}78 \cdot 10^{-3}-\boldsymbol{t}{*}0{,}62 \cdot 10^{-3}-0{,}3711)+$$
$$+1{,}29 \cdot (\boldsymbol{L}{*}9{,}95 \cdot 10^{-5}-4{,}66 \cdot 10^{-3})+1{,}01 \cdot$$
$$\cdot (17{,}7 \cdot 10^{-3}-\boldsymbol{n}{*}0{,}76 \cdot 10^{-5}-\boldsymbol{k}{*}9{,}7 \cdot 10^{-3}))$$

L – path traversed by a drill, t – processing time, k – coefficient indicating presence (1) or absence (0) of oscillating vibrations, n – frequency of spindle rotation, f – double entering angle of the drill, B – wear magnitude, Coefficient of performance models: k* = 0,086944

Mathematical evaluation of holes quality

Evaluation of the accuracy of the holes was carried out using the technique proposed by PhD of ITM Department, Institute of Mechanical Engineering, NTUU «KPI» V. Solodkiy [5]. The technique is based on the method of least squares, which in this case is used to determine parameters xc, yc and r of performing circle for all points of the original curve.

The equation for the circle is written as:

$$(x_i - x_c)^2 + (y_i - y_c)^2 = r^2 \cdot$$

Then the unknown function of the least squares method will look like:

$$f_3 \equiv \left(\left(\sum_{i=1}^{n} x_i - x_c\right)^2 + \left(\sum_{i=1}^{n} y_i - y_c\right)^2 - r^2\right)^2.$$

After differentiation the f_3 by parameter r and equating to 0 the equation will look like:

$$\frac{\partial f_3}{\partial r} = nr^2 - r\sum_{i=1}^{n} x_i^2 + 2rx_c\sum_{in=1}^{n} x_i - nrx_c^2 - R\sum_{i=1}^{n} y_i^2 + 2ry_c\sum_{i=1}^{n} y_i - ny_c^2 = 0.$$

The solution of this equation with respect to the parameter r gives expression to determine radius of the performing circle:

$$r = \frac{1}{\sqrt{n}}\sqrt{nx_c^2 + ny_c^2 - 2x_c\sum_{i=1}^{n} x_i + \sum_{i=1}^{n} x_i^2 - 2y_c\sum_{i=1}^{n} y_i + \sum_{i=1}^{n} y_i^2}\,.$$

Further differentiation of equation f_3 is done by parameter x_c and the expression is obtained:

$$\frac{\partial f_3}{\partial x_c} = \frac{4}{n}\left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} x_i^2 - 2y_c\sum_{i=1}^{n} y_i + \sum_{i=1}^{n} y_i^2\right) - \frac{8}{n}x_c\left(\sum_{i=1}^{n} x_i\right)^2 +$$
$$+\left(2x_c\sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} x_i^3 + 2y_c\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i y_i^2\right) = 0$$

Where determined the coordinate y_c of performing circle center:

$$y_c = \frac{2x_c\left(\sum_{i=1}^{n} x_i\right)^2 - \sum_{i=1}^{n} x_i\left(\sum_{i=1}^{n} x_i^2 + \sum_{i=1}^{n} y_i^2\right) + n\left(-2x_c\sum_{i=1}^{n} x_i^2 + \sum_{i=1}^{n} x_i^3 + \sum_{i=1}^{n} y_i^2 x_i\right)}{-2\sum_{i=1}^{n} x_i\sum_{i=1}^{n} y_i + 2n\sum_{i=1}^{n} y_i x_i}.$$

After differentiation of equation f_3 by parameter y_c the next expression is obtained:

$$\frac{\partial f_3}{\partial y_c} = \frac{C_1 + C_2 + C_3}{\sum_{i=1}^{n} x_i\sum_{i=1}^{n} y_i - n\sum_{i=1}^{n} x_i y_i} = 0,$$

$$C_1 = \sum_{i=1}^{n} x_i^3\left(\sum_{i=1}^{n} x_i\right)^2 + n\sum_{i=1}^{n} x_i^2 y_i\sum_{i=1}^{n} x_i y_i - 2nx_c\left(\sum_{i=1}^{n} x_i y_i\right)^2 -$$
$$-2x_c\left(\sum_{i=1}^{n} x_i\right)^2\sum_{i=1}^{n} y_i^2 - n\sum_{i=1}^{n} x_i^3\sum_{i=1}^{n} y_i^2 - \sum_{i=1}^{n} y_i\sum_{i=1}^{n} x_i y_i\sum_{i=1}^{n} y_i^2 \quad ,$$

$$C_2 = \sum_{i=1}^{n} x_i^2\left(2x_c\left(\sum_{i=1}^{n} y_i\right)^2 + \sum_{i=1}^{n} y_i\sum_{i=1}^{n} y_i x_i - 2nx_c\sum_{i=1}^{n} y_i^2\right) +$$
$$+\left(\sum_{i=1}^{n} y_i^2\right)^2\sum_{i=1}^{n} y_i^2 x_i - n\sum_{i=1}^{n} y_i^2\sum_{i=1}^{n} y_i^2 x_i \quad ,$$

$$C_3 = \sum_{i=1}^{n} x_i\left(-\sum_{i=1}^{n} x_i^2 y_i\sum_{i=1}^{n} y_i + \sum_{i=1}^{n} y_i^2\left(\sum_{i=1}^{n} y_i^2 + \sum_{i=1}^{n} x_i^2\right)\right) +$$
$$+\sum_{i=1}^{n} x_i\left(\sum_{i=1}^{n} y_i\left(4x_c\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} y_i^3\right)\right) + n\sum_{i=1}^{n} x_i y_i\sum_{i=1}^{n} y_i^3 \ .$$

Where determined the coordinate x_c of performing circle center:

$$x_c = \frac{a_1 + a_2}{a_3},$$

$$a_1 = n\sum_{i=1}^{n} y_i x_i^2\sum_{i=1}^{n} y_i x_i - \sum_{i=1}^{n} x_i^2\sum_{i=1}^{n} y_i\sum_{i=1}^{n} y_i x_i - \sum_{i=1}^{n} y_i\sum_{i=1}^{n} y_i x_i\sum_{i=1}^{n} y_i^2 +$$
$$+\sum_{i=1}^{n} x_i^3\left(\left(\sum_{i=1}^{n} y_i\right)^2 - n\sum_{i=1}^{n} y_i^2\right) + \left(\sum_{i=1}^{n} y_i\right)^2\sum_{i=1}^{n} y_i x_i^2 ,$$

$$a_2 = \sum_{i=1}^{n} x_i\left(-\sum_{i=1}^{n} y_i x_i^2\sum_{i=1}^{n} y_i + \sum_{i=1}^{n} x_i^2\sum_{i=1}^{n} y_i^2 + \left(\sum_{i=1}^{n} y_i^2\right)^2 - \sum_{i=1}^{n} y_i\sum_{i=1}^{n} y_i^3\right) -$$
$$-n\sum_{i=1}^{n} y_i^2\sum_{i=1}^{n} x_i y_i^2 + n\sum_{i=1}^{n} y_i x_i\sum_{i=1}^{n} y_i^3 ,$$

Obtained equations allow directly determining parameters x_c, y_c and r of performing circle that optimally passes through the array of points x_i, y_i ($i = 1 \ldots n$).

Thus, after entering array of points coordinates of hole the replacing optimal circle was obtained (Fig. 11).

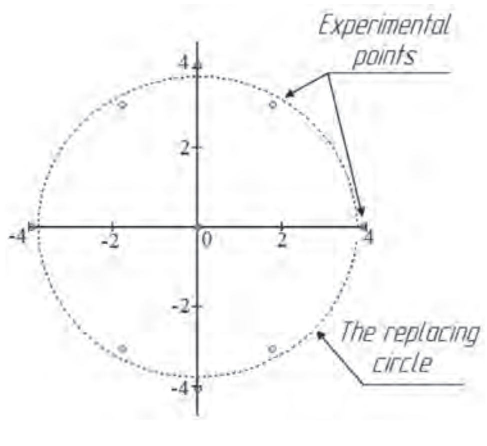
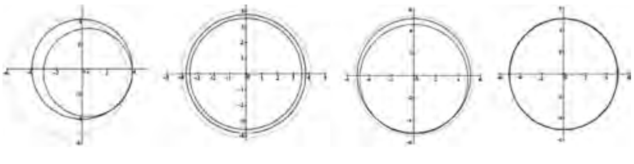


Fig. 11. Building an optimal performing circle for the experimental points

The next step is to create an array of radiuses from determined performing circle center to the experimental points. Then three points with the least distance from the center of the performing circle are determined, which are used to build inscribed circle. For three points the most distant from the performing circle center described circle is constructed. The final step is the optimal combination of inscribed and described circles. As a result of the calculations the following results were obtained.



a. 2φ=120˚ standard drilling b. 2φ=110˚ reverse drilling c. Two cutting edges drill d. Step drill

Fig. 12. Optimal, inscribed and described circles obtained by the experimental points

Based on such assessment coincidence degree of radiuses and centers of inscribed and described circled is considered to be the indication of hole accuracy. With the applied methodology it is possible to obtain the deviation of circles radiuses and centers namely:

R_{c_v} – Rc – deviation between the radiuses of the optimal and inscribed circles;

R_{c_o} – Rc – deviation between the radiuses of the optimal and described circles;

$\sqrt{(X_{c\_v}-X_c)^2+(Y_{c\_v}-Y_c)^2}$ – deviation between the centers of the optimal and inscribed circles;

$\sqrt{(X_{c\_o}-X_c)^2+(Y_{c\_o}-Y_c)^2}$ – deviation between the centers of the optimal and described circles;

$\sqrt{(X_{c\_o}-X_{c\_v})^2+(Y_{c\_o}-Y_{c\_v})^2}$ – deviation between the centers of the inscribed and described circles;

Evaluation results are shown on Fig. 13:

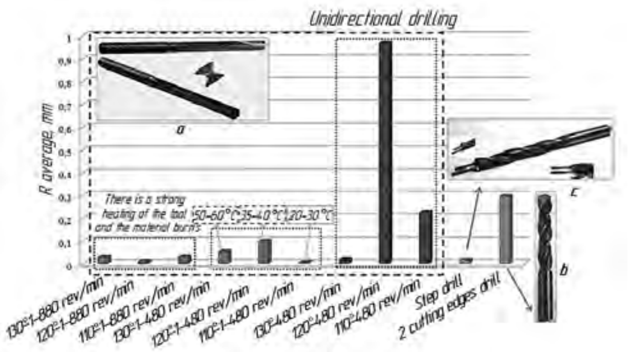


Fig. 13. Diagram of average deviation between centers of the circles obtained for tool samples

The diagram shows that the largest average deviation occurs for 2 cutting edges drills, as well as ˚for samples 1 and 2 of reversing drill at unidirectional drilling. With a spindle frequency 880 rev/min. there is a strong tool heating and material burns around the holes, which drastically reduces the quality. So, the optimal geometry is the dual entering angle in terms of 110˚ with a frequency 480 rev/min. For unidirectional drilling 2 cutting edges drill with 2φ = 130˚ gives small holes deviation from roundness.

Measurement the temperature of cutting zone

Temperature arising during cutting PCM, affects not only the tool wear but also to the quality of the machined surface. Specifically thermodestruction of PCM layers does the using of such detail impossible [6].

In this paper we applied the temperature measurement using natural thermocouple as follows:

Figure 14: 1 – tool 2 – sample of carbon fiber, 3 – substrate, 4 – Place of a millivoltmeters contact input 5 – brush, which is attached to a voltmeter and a second contact which is in immediate contact with the tool, 6 – millivoltmeter to measure the thermopower.

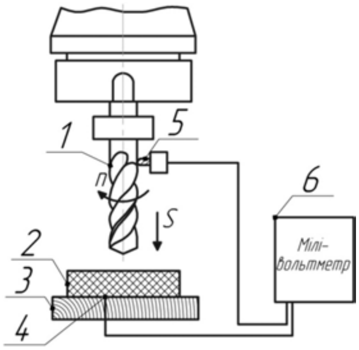


Fig. 14. Scheme of temperature measuring of cutting zone

Fig. 15. Accessories for temperature measuring

Fig. 16. Laser pyrometer, which was used for the study

Figure 7 shows a way to fix a contact of thermocouple to the instrument. In Figure 8 submitted an image of laser pyrometer, which was used to measure the temperature of the cutting zone. Temperature dependence for the oscillating tool is shown in Figure 17. The diagram shows that the temperature on the main cutting edge of the tool almost twice exceeds the temperature of the side cutting edge.

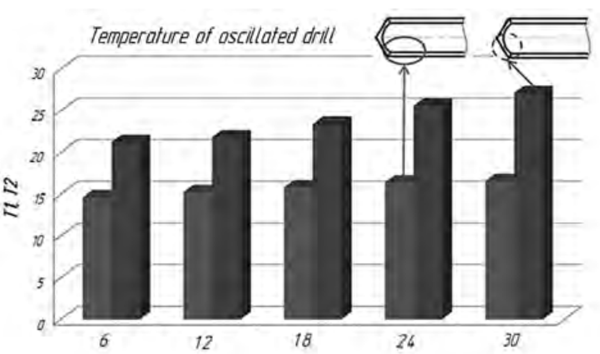


Fig. 17. The temperature of oscillating drill

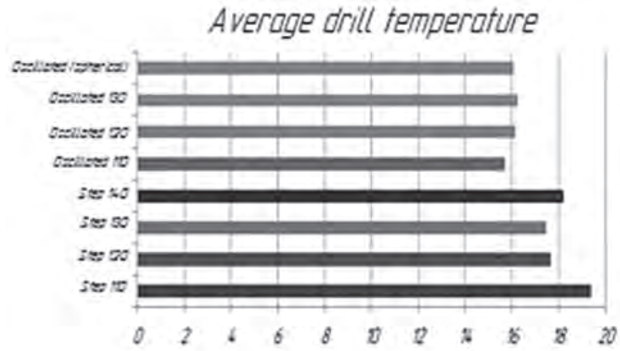


Fig. 18. The diagram of average temperature of drills with different construction

In Figure 18 presented the average temperature diagram of instruments with various designs. For comparison, the diagram shows the indications for step drills.

The graphs (Fig. 19) and the diagram show that among the step drills the smallest heating occurs in the instrument with $2\varphi = 130^\circ$, for the oscillating drill – $2\varphi = 110^\circ$. As a result of research the calibration characteristics of thermocouples was obtained:

$$T = 5{,}094\ U + 6{,}0842$$

Where T – temperature of cutting zone, U – value of thermopower, mV.

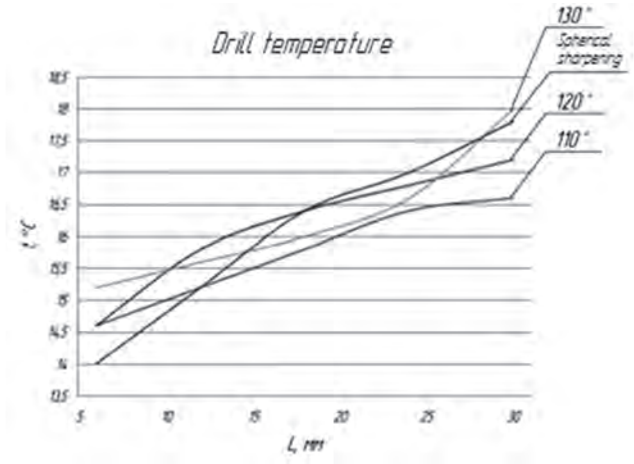


Fig. 19. Temperature dependence for drill of the way and construction

Processing of inclined surfaces.

The method of the oscillating drilling made it possible to process of inclined surfaces. This issue is important when it is necessary to get the high quality of hole in not rectilinear (spherical) surface, which is not used for mounting panels or components (such as air vents, etc.).

Figure 20 depicts anchorages of PCM sample so that the surface is inclined at an angle to the horizontal with the ability to change the angle. The angles of inclination of the PCM sample plane were varied from 5° to 45°. In order to processing four samples of oscillating drill were selected: drill with a spherical sharpening and the drills with $2\varphi = 110^\circ$, 120° and 130° [1].

The various tools designs and processes with changing the inclination angle of the PCM sample surface were tested. It was found that with increasing of dual main angle in terms 2φ, holes quality is significantly reduced. Figure 21 shows the view of the hole at an inclination of the PCM plane 45° for drill with $2\varphi = 110^\circ$ (a) and $2\varphi = 130^\circ$ (b), and view of hole at the exit of drill $2\varphi = 110^\circ$ (d).

The figure shows that during processing of PCM by the drill with $2\varphi = 130^\circ$ there is deviation from the axis of the instrument, which making a formed hole unusable. While the processing by drill with $2\varphi = 110^\circ$, the hole quality is much higher, there is a slight fibration of fibers at the input of tool.

Figure 21 (a) shows the view of hole for oscillating drill with a spherical sharpening for the angle of PCM surface inclination $\alpha = 15^\circ$. There are chips on the input and output of the tool from material. That is this bit enables to obtain the high holes quality only during PCM processing in the perpendicular direction.

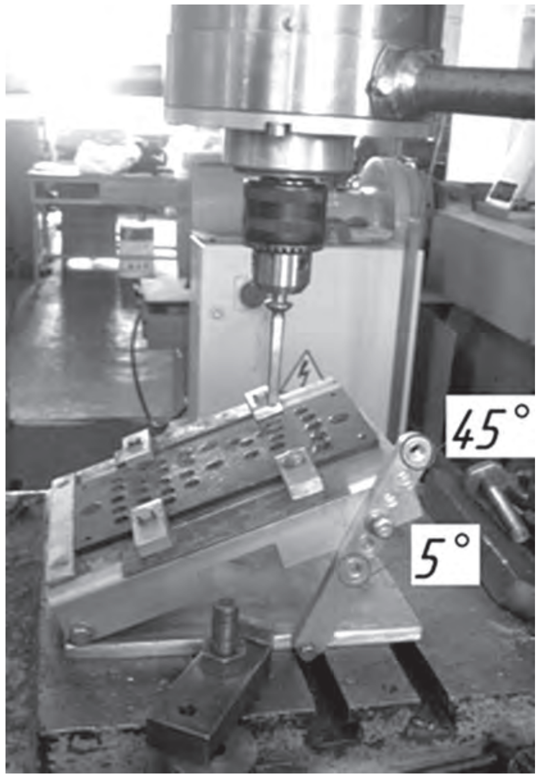
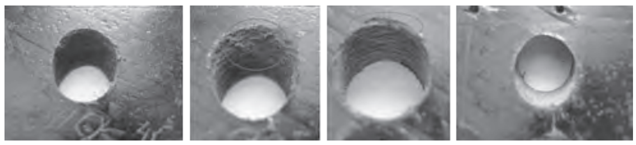


Fig. 20. Accessories for processing PCM at an angle to the horizontal plane with the ability to change the angle of inclination



a b c d

Fig. 21. View of holes in the PCM for the oscillating drill with $2\varphi = 110^\circ$ (a) and $2\varphi = 130^\circ$ (b)

The angle of the PCM plane $\alpha = 45^\circ$; c – view of hole treated with a spherical sharpening drill ($\alpha = 15^\circ$); d – the view of hole in the instrument exit ($2\varphi = 110^\circ$, $\alpha = 45^\circ$)

Conclusions and perspective research directions. As a result of research holes accuracy in composite materials (carbon fiber) using computer methods based on mathematical method of least squares was assessed. This method is applicable in the absence of the possibility to measure the resulting holes accuracy using Round measured device and at the presence of a set of obtained circle points coordinates.

1. Program proposed by V. Solodkiy for the construction of the performing circle that optimally passes through the experimental points, made it possible

to accurately calculate distance between the centers of the circles, corresponding to the most distant and closest experimental points to the optimal circle center. The hole is the most accurate when radiuses and centers of received from the program circles coincide.

2. After comparing 2 cutting edges drill, step and reversing drills, it was shown that for 2 cutting edges drill, drills with 2φ = 120° and 110° for unidirectional drilling, there is the greatest deviation from roundness (the worst holes accuracy). Holes accuracy increases applying oscillating vibrations on drill samples, but with increase of spindle frequency (from 480 rev/min to 880 rev/min) the tool heats and holes quality is reduced by thermal destruction of carbon fiber layers. After processing with step drill it was determined that step drill with dual entering angle $2\varphi_2$ = 130° is the optimal of four instrument samples. This drill produces holes of the best quality in PCM, and the wear value is smaller for this geometry (0.131 mm, for wear rate 0.032 mm/s). That is the step drill in unidirectional drilling and oscillating drill with 2φ = 110° for bidirectional drilling are optimal. Comparing to studies of 3 cutting edges and step drills, temperature after processing decreased by 10% for oscillating drill. Using a bidirectional movement of drills it was determined that tool wear value decreases by 8%, and performance holes accuracy increases by 10%.

3. Perspective direction of research is receiving the temperature dependency along the cutting edge of the tool, more accurate research of tool geometry within the 2φ = 110° ± 5° and improving drill design, the study of other device modes for oscillating drilling work.

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Булах І.О., Глоба О.В., Солодкий В.І.
Національний технічний університет України
«Київський політехнічний інститут»

ДОСЛІДЖЕННЯ ТЕМПЕРАТУРНОЇ ЗАЛЕЖНОСТІ І ОЦІНКА ЯКОСТІ ОТВОРІВ ПРИ ОСЦИЛЮЮЧОМУ СВЕРДЛІННІ ПКМ

Анотація
Досліджений процес осцилюючого свердління полімерних композиційних матеріалів (ПКМ). За допомогою методу групового урахування аргументів (МГУА) отримана багатофакторна математична залежність параметрів процесу різання, таких як зношування, температура, геометричні параметри інструмента, а також коригуючи коефіцієнти моделі. Виходячи з методології, заснованої на методиці найменших квадратів, проведена оцінка якості отворів (відхилення від круглості). Проведені вимірювання температури зони різання за допомогою природної термопари і лазерного пірометра. Порівняні отримані результати. Досліджене свердління нахилених поверхонь.
Ключові слова: полімерний композиційний матеріал, осцилюючий рух свердла, оцінка якості отворів, метод найменших квадратів, температура зони різання, нахилені поверхні.

Булах И.А., Глоба А.В., Солодкий В.И.
Национальный технический университет Украины
«Киевский политехнический институт»

ИССЛЕДОВАНИЕ ТЕМПЕРАТУРНОЙ ЗАВИСИМОСТИ И ОЦЕНКА КАЧЕСТВА ОТВЕРСТИЙ В ПРОЦЕССЕ ОСЦИЛЛИРУЮЩЕГО СВЕРЛЕНИЯ ПКМ

Аннотация
Исследован процесс осциллирующего сверления полимерных композиционных материалов (ПКМ). При помощи метода группового учёта аргументов (МГУА) получена многофакторная зависимость параметров процесса резания таких, как износ, температура, геометрические параметры инструмента, а так же корректирующие коэффициенты модели. Исходя из методологии, основанной на методе наименьших квадратов, проведена оценка качества отверстий (отклонение от округлости). Проведены измерения температуры зоны резания при помощи естественной термопары и лазерного пирометра. Проведено сравнение полученных результатов. Исследовано сверление наклонных поверхностей.
Ключевые слова: полимерный композиционный материал, осциллирующее движение сверла, оценка качества отверстий, метод наименьших квадратов, температура зоны резания, наклонные поверхности.