How to cite this article:

Authors: Elżbieta Doluk, Józef Kuczmaszewski, Paweł Pieśko

Title of article: „Wpływ zmiany parametrów cięcia wodno-ściernego na jakość przecinania kompozytowych struktur przekładkowych" ("The influence of changing the parameters of water-abrasive cutting on the quality of cutting composite cross-section structures")

Mechanik, Vol. 91, No. 7 (2018): pages 476–478

DOI: https://doi.org/10.17814/mechanik.2018.7.59

The influence of changing the parameters of water-abrasive cutting on the quality of cutting composite cross-section structures

Wpływ zmiany parametrów cięcia wodno-ściernego na jakość przecinania kompozytowych struktur przekładkowych

ELŻBIETA DOLUK
JÓZEF KUCZMASZEWSKI
PAWEŁ PIEŚKO *

Presented are results of the surface quality sandwich composites (aluminum alloy EN AW-2024 and CFRP) by using an abrasive water-jet. The experiments were conducted with different speed of cutting, pressure of the abrasive water, mass flow rates, entry side of the stream and quantity of composite layers. The analysis has been studied based on received bevel angle values.

KEYWORDS: spacer composite, abrasive water jet, bevel angle, surface quality

Composites are a group of engineering materials that have been playing an increasingly important role in many areas of modern technology since the 19th century. This is due to their physicochemical properties [14]. Constant efforts to reduce production costs have contributed to the widespread use of sandwich-type sandwich composites.

These materials are constructed of two or more layers in which the outer covers are separated by a spacer layer in the form of a light core. Due to this, layered composites feature a light, stiff, yet durable construction.

These materials were used mainly in the aviation industry, including for the construction of aircraft fuselages. The processing of composite materials involves the necessity of overcoming many difficulties, including selection of appropriate tools and their intensive wear, the occurrence of the phenomenon of delamination or removal of harmful dust generated during processing [8].

The specific construction of composite prescription structures imposes the selection of a proper technique for their machining. The lack of a well-thought-out strategy may in this case cause deterioration or loss of the material's functional properties [7]. Cutting of composite sandwich structures also requires careful selection of process parameters. These materials are characterized by considerable heterogeneity, which leads to rapid wear of cutting tools [1, 3].

An alternative technique for the processing of composite composites is cutting with a high-pressure water-abrasive jet. Hydro-abrasive cutting has a number of advantages in comparison with other cutting methods. These include: no heat zone formation, no material melting, no need for sharpening of the cutting tool, pressure control, minimal deformation of the cut material, tolerances of 0.1÷0.3 mm, the ability to cut a wide spectrum of materials [12].

The main disadvantages of this method of cutting are: formation of post-treatment traces in places where the water-abrasive stream impacts, and beveling of the cut surfaces.

The basic parameters of hydro-abrasive cutting are: cutting speed, water-abrasive stream pressure and cutting medium expense [2, 4-6, 9, 10, 13]. The study of the influence of these process parameters on the quality of the intersected edges of composite sandwich structures will enable their value to be selected in such a way as to obtain the desired quality with maximum process efficiency.

Research methodology

The aim of the experiment was to investigate the impact of cutting speed, jet pressure, abrasive volume and the type of composite structure (two- or three-layer) and the material of the water-abrasive stream input (tool input from the side of the carbon plate or aluminum alloy plate) to the quality of the cuts edge of a sandwich type composite.

The scope of the study included gluing, cutting and measuring the bevel angle of the sample surfaces using a laboratory microscope.

A 500 × 500 mm and 6 mm thick board was used, made of EN AW - 2024 aluminum alloy (fig. 1a), and a 500 × 500 mm carbon plate with a thickness of 6 mm, made by an autoclave method, on a warp made of epoxy resin with a pre-impregnated fabric made of carbon fiber with alternating fiber arrangement (fig. 1b).

* Mgr inż. Elżbieta Doluk (elzbieta.doluk@interia.pl), prof. dr hab. inż. Józef Kuczmaszewski (j.kuczmaszewski@pollub. pl), dr inż. Paweł Pieśko (p.piesko@pollub.pl) – Politechnika Lubelska

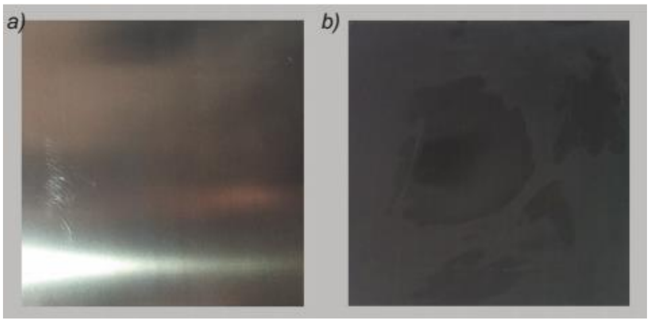

Fig. 1. Materials used in the study: *a*) aluminum alloy plate EN AW-2024, *b*) carbon board

A delamination fabric was applied to the surface of both panels, protecting the panel against the influence of the coating and shaping the developed topography of the surface for the purpose of gluing.

Preparation of materials for bonding included: initial degreasing of plates with acetone, manual grinding with Scotch-Brite 07447+ abrasive cloth, re-degreasing with acetone, performing Water Break Test, applying to the surfaces of 3M AC 130 boards. The panels were glued with a 3M Scotch two-component structural adhesive - Weld Structural Epoxy Adhesive EC-9323 B/A, mixed in a weight ratio of 100: 27 (in accordance with the instructions), applied on both sides.

During assembly, the plates were placed in a vacuum bag at a pressure of 0.1 bar for 24 hours and then aged for seven days under ambient conditions.

The boards were glued in the following combinations:
- carbon composite + EN AW-2024 aluminum alloy (double-layer structure),
- EN AW-2024 aluminum alloy + carbon composite + EN AW-2024 aluminum alloy (three-layer structure).

The process of cutting samples was carried out using the COMBO portal saw from Eckert AS. The cutting height was 3 mm. The bevel angle of the specific edges was measured using a Keyence VHX-500 laboratory microscope.

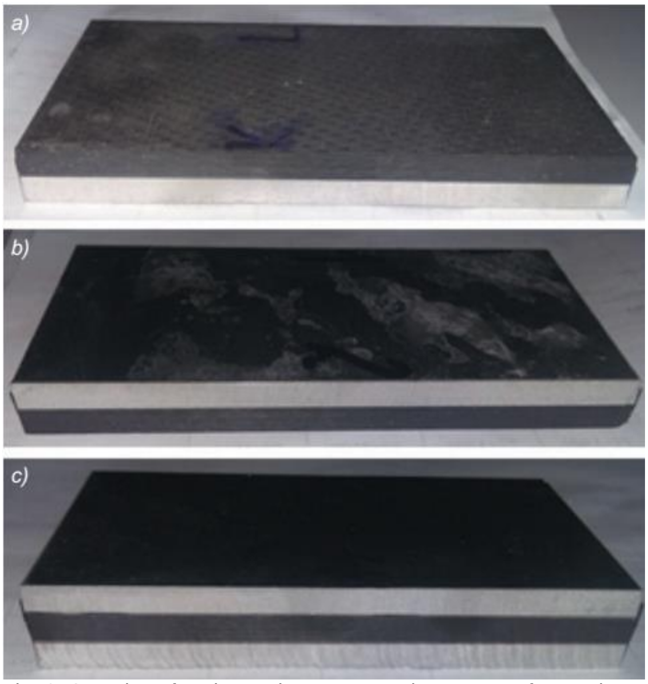

Fig. 2. Samples after the cutting process: a) structure of a two-layer carbon composite + aluminum alloy EN AW-2024, b) double-layer structure of aluminum alloy EN AW-2024 + carbon composite, c) three-layer structure

Tab. I shows the normative chemical composition of the tested material was compiled. The aluminum alloy used in the test has good strength properties, is characterized by low resistance to oxidation and corrosion and poor weldability. This material is used most often for the construction of air constructions.

The glued, two-layer composite structure was placed on 26 samples with dimensions of 60 × 120 mm. 13 samples were cut from the side of the carbon composite (fig. 2a) and 13 samples from the aluminum alloy side (fig. 2b). The three-layered structure was cut into 13 samples with dimensions of 60 × 120 mm (fig. 2c).

TABLE I. Chemical composition of the aluminum alloy EN AW-2024 [11]

Element	Content, %
Si	0,5
Fe	0,5
Cu	3,8÷4,9
Mn	0,3÷0,9
Mg	1,2÷1,8
Cr	0,01
Zn	0,25
Ti	0,15
Zr	<0,10

A research plan is included in the table. The ranges of process parameters were selected based on the manufacturer's recommendations (technical and operational documentation), literature analysis and experience.

TABLE II. Experiment plan

Number of experi-ment	Code value of the parameter			Actual value of the parameter		
	Vc, mm/min	P, bar	Q, kg/min	Vc, mm/min	P, bar	Q, kg/min
1	V_1	P_5	Q_1	50	3500	0,5
2	V_1	P_4	Q_1	50	3000	0,5
3	V_1	P_3	Q_1	50	2500	0,5
4	V_1	P_2	Q_1	50	2000	0,5
5	V_1	P_1	Q_1	50	1500	0,5
6	V_2	P_1	Q_1	75	1500	0,5
7	V_3	P_1	Q_1	100	1500	0,5
8	V_4	P_1	Q_1	200	1500	0,5
9	V_5	P_1	Q_1	400	1500	0,5
10	V_1	P_1	Q_2	50	1500	0,4
11	V_1	P_1	Q_3	50	1500	0,5
12	V_1	P_1	Q_4	50	1500	0,2
13	V_1	P_1	Q_5	50	1500	0,1

Explanation of symbols: Vc- cutting speed, P- pressure of the abrasive jet, Q- abrasive expenditure

Test results

After the cutting process and measurements of the bevel angle of the samples, the obtained results were analyzed in the function of the cut parameters adopted.

The results of the experiment were divided into three parts depending on the configuration of the cut:

- cutting the two-layer structure from the side of the carbon composite,
- cutting the double-layer structure from the aluminum alloy side,
- cutting the three-layer structure.

After the completion of the cutting process, the samples were subjected to a preliminary inspection, the purpose of which was to determine whether the specimen was cut, whether there was a delamination process, whether there were chippings between the combined layers and what traces of structure were formed on the surfaces of the cut samples.

Fig. 3 shows the change in the bevel angle value depending on the adopted cutting parameters.

On the basis of the graph analysis (fig. 3a) it can be seen that the smallest value of the bevel angle for cutting the two-layer structure with the spray input from the side of the composite was obtained for sample No. 1, and the largest - for sample No. 11. In the case under consideration the adopted parameters were sufficient to cut all samples.

When cutting the double-layer structure on the aluminum side (fig. 3b) the bevel angle reached the lowest value for samples No. 1 and No. 4, and the highest - for sample No. 13. The parameters adopted in the study were not enough to cut samples 8 and 9 .

The cutting of the three-layer structure (fig. 3c) with the assumed parameters turned out to be ineffective - eight out of 13 samples were not cut (empty fields on the chart). For this cutting configuration, the lowest bevel angle was obtained for samples no. 1 and 2, and the highest for sample no. 3.

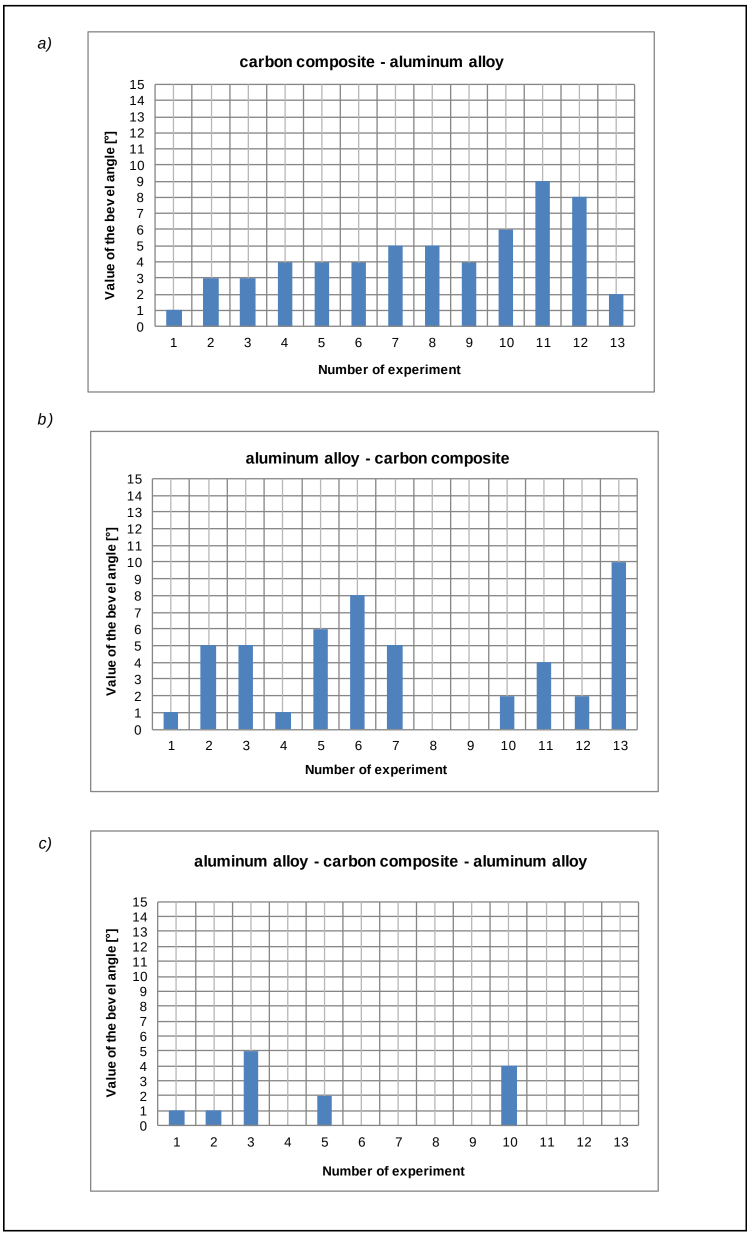

Fig. 3. Value of the bevel angle of the surface during cutting: *a*) the structure of the two-layer carbon composite + aluminum alloy EN AW-2024, *b*) the double-layer structure of the aluminum alloy EN AW-2024 + the carbon composite, *c*) the three-layer structure

Conclusions

Analysis of the test results and the visual assessment of the intersection area allowed to formulate the following conclusions:

- no delamination occurred when cutting samples; no cases of damage to the adhesive joint were noted;
- cutting from the side of the carbon board is more advantageous for the quality of the surface being cut, i.e. there is a smaller bevel angle, traces are not visible on the cut surfaces, all samples have been cut and better cut surface quality compared to the process of the water-abrasive stream from the side aluminum alloy (the deflection of the stream in the depth of the aluminum alloy is higher);
- phenomenon of "drawing in" the stream when reaching the carbon composite layer has been observed;
- the best parameter of quality control of the cut surfaces turned out to be the pressure of the stream - the increase in pressure causes the reduction of the bevel angle value;
- higher pressure of the stream allowed to increase the thickness of the cut materials (three-layer structure) without a significant decrease in the quality of the cut surface compared to the materials with a smaller thickness (two-layer structure);
- increasing the thickness of the layered composite without changing the assumed parameters results in the formation of large waviness in the zone of the lower edge of the cut surface;
- increase in the value of the abrasive output causes a reduction in the cutting depth of the sandwich structure - this is related to the throttling of the forming nozzle and the reduction of the erosive capacity of the stream.

The presented test results confirmed the validity of using abrasive water cutting to cut non-uniform materials, such as composite sandwich structures. The key parameter enabling the most effective control of the quality of the cut surfaces is the pressure of the abrasive jet.

REFERENCES

1. Boczkowska A., Krzesiński G. „*Kompozyty i techniki ich wytwarzania*". Warszawa: Oficyna Wydawnicza Politechniki Warszawskiej, 2016.
2. Borkowski J., Benkowska M. „Wpływ głównych parametróa.w obróbki wysokociśnieniową strugą wodno-ścierną na jakość powierzchni przecięcia". *Archiwum Technologii Maszyn i Automatyzacji*. 2 (2006): pp. 11–18.
3. Greń K., Szatkowski P., Chłopek J. „Characterictics of failure mechanisms and shear strength of *sandwich* composites". *Composites Theory and Practice*. 4 (2016): pp. 255–259.
4. Hlavac L., Hlavacova I., Kalicinsky J., Fabian S., Mestanek J., Kmec J., Madra V. „Experimental method for the investigation of the abrasive water jet cutting quality". *Journal of Materials Processing Technology*. 209 (2009): pp. 6190–6195.
5. Klimpel A. „Cięcie strumieniem wody. Technologia i zastosowanie przemysłowe – cz. II". *Stal, Metale & Nowe Technologie*. 3–4 (2013): pp. 18–23.
6. Kłonica M., Kuczmaszewski J. „Analiza wybranych cech struktury geometrycznej powierzchni konstrukcji przekładkowych po cięciu hydoabrazywnym". *Przegląd Mechaniczny*. 11 (2016): pp. 44–48.
7. Królikowski W. „*Polimerowe kompozyty konstrukcyjne*". Warszawa: Wydawnictwo Naukowe PWN, 2012.
8. Józwik J., Tofil A., Banaszek M., Kuric I. „Wybrane aspekty obróbki skrawaniem polimerowych kompozytów włóknistych i oceny chropowatości powierzchni". *Postępy Nauki i Techniki*. 15 (2012): pp. 205–220.
9. Mazurkiewicz A. „Projektowanie procesu technologicznego oraz jakości cięcia strumieniem wodno-ściernym". *Stal, Metale & Nowe Technologie*. 5–6 (2017): pp. 66–73.
10. Ochal P., Kuczmaszewski J., Kłonica M. „Ocena powierzchni struktur metalowo-kompozytowych po cięciu wysokociśnieniową strugą wodno-ścierną". *Mechanik*. 5–6 (2017): pp. 436–438.
11. PN-EN 573-1:2006 Aluminium i stopy aluminium – Skład chemiczny i rodzaje wyrobów przerobionych plastycznie – Część I: System oznaczeń numerycznych.
12. Skoczylas A., Zaleski K., Kowalczyk H. „Badania porównawcze chropowatości powierzchni stali, stopu aluminium i stopu tytanu po cięciu strumieniem wodno-ściernym". *Innowacyjne procesy wytwórcze.* Lublin: Politechnika Lubelska, 2013.
13. Spadło S., Krajcarz D., Dudek D. „Wpływ wybranych parametrów procesu przecinania strugą wodno-ścierną na dokładność geometryczną i jakość powierzchni otworów cylindrycznych". *Mechanik*. 8–9 (2015): pp. 308–312.
14. Uścimowicz R. „*Procesy odkształcania metalowych kompozytóa.w warstwowych*". Białystok: Oficyna Wydawnicza Politechniki Białostockiej, 2015. ■

Translation of scientific articles, their computer composition and publishing them on the website www.mechanik.media.pl by original articles in Polish is a task financed from the funds of the Ministry of Science and Higher Education designated for dissemination of science.

Ministry of Science and Higher Education
Republic of Poland