Assessement of surface finish quality of metal/composite compound structures as cut by abrasive water-jet

Ocena powierzchni struktur metalowo-kompozytowych po cięciu wysokociśnieniową strugą wodno-ścierną

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DOI: https://doi.org/10.17814/mechanik.2017.5-6.59

The paper presents selected results of the surface quality measurements on the as cut the samples bonded. The test materials were conventional lap bonded samples or sandwich bonded samples in different arrangements. Water jet method was applied under variable v_f.

KEYWORDS: abrasive water jet, adhesive joints, surface layer

Cutting operation is occurring in many manufacturing processes. Various materials are subject to cutting - from metal alloys and polymer plastics, from mineral raw materials to natural materials - are used in a wide range of human activities [1-3]. Recent years have been the period of dynamic development of cutting technology with high pressure water-abrasive blades [3, 7, 8, 10, 11]. This is due, among others. From the numerous advantages of this process (including the ability to apply it to a wide range of materials and in many areas of technology - such as aviation, automotive or machine construction) and technical progress that has allowed a significant increase in water pressure.

Literature can provide information on the advantages and uses of high-pressure abrasive blades for cutting different materials [9], but there is no data on its use for cutting glued sandwich structures.

Today, in the technics, glued structures are often subjected to further processing, such as milling or cutting. Due to the fact that these operations may be end-operations, it is important to preserve the uniformity of the adhesive bond. So far, studies on cutting of glued polymeric materials indicate the possibility of processing such structures without significant surface defects and delamination or other defects in the glue joint zone [4-6, 12].

Methodology of research

Experimental research was conducted in two stages. The first included gluing of samples from different materials in two- and three-layer structures of various combinations, sandwiches. In the second stage, the finished samples were cut into high pressure water-abrasive stream with predetermined technological parameters of the process. Samples made of the following materials were used:

- aluminum alloy 2017A (sample dimensions: 100 × 20 × 2 mm),
- polyamide PA6 (sample size: 100 × 25 × 4 mm),
- 316L steel (sample size: 100 × 25 × 1.5 mm),
- carbon composite (sample dimensions: 100 × 20 × 1.5 mm).

Aluminum alloy 2017A and 316L steel were cleaned with abrasive cloth. The carbon composite was mechanically treated with a P320 grit, while the polyamide PA6 was a P100 grit. Each of the materials was washed three times with Loctite 7063 remover.

The samples were glued in the following combinations: carbon composite - PA6 polyamide, aluminum alloy 2017A - polyamide PA6, 316L steel - carbon composite, polyamide PA6 - carbon composite - 316L steel, 316L steel - polyamide PA6 - carbon composite, PA6 polyamide - carbon aluminum 2017A, aluminum alloy 2017A - polyamide PA6 - carbon composite. Epidian 6 epoxy resin with a PAC hardener at a mass ratio of 100: 70 was used to bond the materials.

COMBO portal cutter by ECKERT was used for sample cutting. Each sample was cut six times (with a fixed feed rate v_f = 200, 500 and 1000 mm/min) on both sides of the spacer construction. The jet pressure was 350 MPa and the nozzle distance from the specimen was 3 mm.

Keyence VHX-5000 microscope was used to visualize and measure the chamfer angle resulting from the abrasive water-jet cutting.

Test results

In order to generally assess the quality of the cut surfaces of the samples after cutting with high pressure abrasive blades, their initial inspection was carried out. During these observations the first differences in surface quality were observed, depending on the feed rate and the type of cut material used. The smallest defects of cut surfaces revealed at the lowest feed rate: vf = 200 mm / min. As the speed was increased, more visible traces appeared, such as traces of deflection, crushed material or burrs. Exemplary cut surfaces are shown in fig. 1 and fig. 2.

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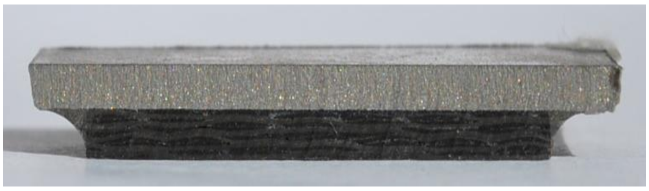

Fig. 1. Visible tilting traces in a two-layer structure 316L steel - carbon composite in the case of cutting at feedrate v_f = 1000 mm/min

Fig. 2. Visible tilting traces in a three-layer structure 316L steel - carbon composite - PA6 polyamide at cutting speed v_f = 1000 mm/min

On the photos, it can be seen traces characteristic of the high-pressure water-abrasive jet. When analyzing two- and three-layer structures, it was not observed that for any of the cut materials the surface defects often occurred or were more intense - their character was accidental.

Keyence VHX-5000 microscope was used for sample observation at 700× magnification. It was checked for abnormal changes at the interface between glued materials and other characteristic phenomena associated with the dynamics of the cutting process.

Fig. 3 shows the photograph of the intersection of one of the analyzed samples. There are differences in surface topography between the inlet and outlet zones of the abrasive jet.

During the microscopic observation of each structure it was noted that in most of the analyzed cases there was a tendency to narrow the stream toward the exit (fig. 4).

Fig. 3. View of the structure intersection: aluminum alloy 2017A (input zone) - carbon composite - polyamide PA6 (output zone)

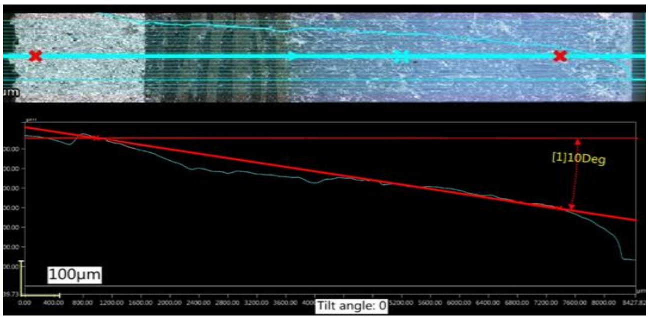

Fig. 4. Method of measuring the bevel angle of the surface on the example of three-layer structure: polyamide PA6 - carbon composite - aluminum alloy 2017A

The bevelling angle values differ depending on the combination of materials, but there are some exceptions to this rule. One of them is a structure in which a 316L combination of carbon steel or 316L steel, polyamide PA6 and carbon composite occurs.

Both in the case of cutting two- and three-layer structures, at the interface between 316L and the carbon composite, a sudden change in bevelling angle of the cut surface occurs. Entering 316L steel, the plane tapers, and then, reaching the adhesive groove between the 316L and the carbon composite, expands rapidly towards the exit (fig. 5 and fig. 6).

However, the described situation of the rapid change of bevel angle only occurs when the steel 316L is traveling towards the carbon composite. If, however, the cutting process starts on the carbon composite side, the stream is narrowed (fig. 7).

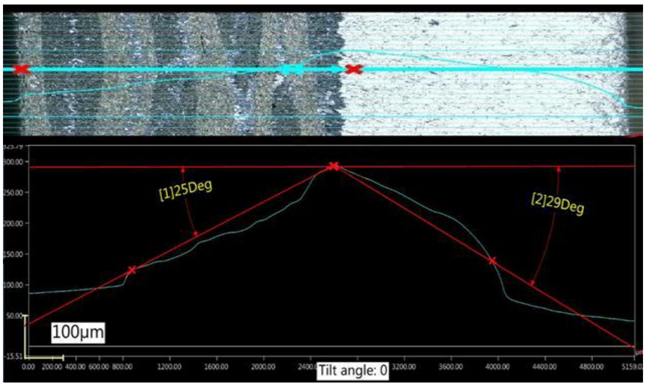

Fig. 5. Bevel angles of intersection of two-layer structure 316L steel - carbon composite in the case of cutting at feed rate v_f = 500 mm/min.

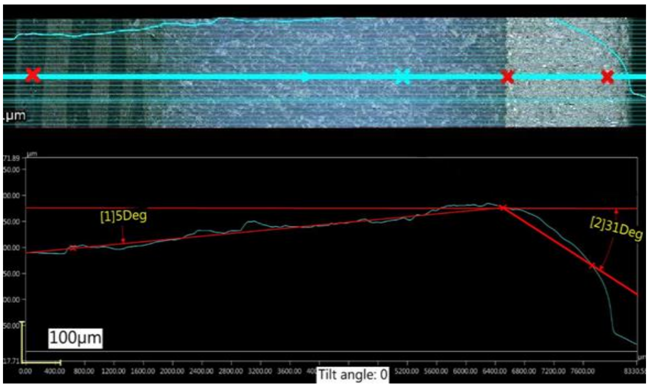

Fig. 6. Angle of cross-section of the three-layer structure 316L steel - polyamide PA6 - carbon composite in the case of cutting at feedrate v_f = 200 mm/min

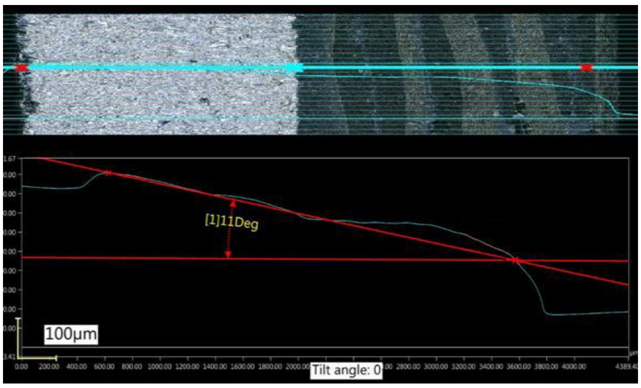

Fig. 7. Angle of intersection of two-layer intersection of carbon composite structure - 316L steel in case of cutting at feedrate v_f = 200 mm/min

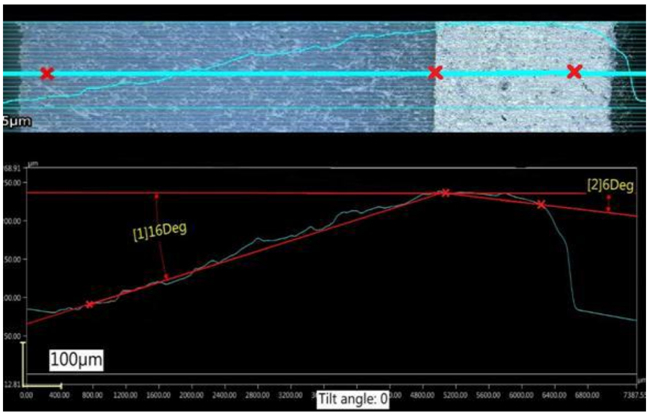

Fig. 8. Bevel angles of the intersection of the two-layer aluminum alloy structure 2017A - Polyamide PA6

Another variant analyzed was the combination of aluminum alloy 2017A and polyamide PA6 (fig. 8). There was also a change in the bevelling angle of the intersection, but not as sudden as 316L and composite.

In the opposite case - when the cutting process started from polyamide PA6 towards aluminum alloy 2017A - a slight narrowing of the stream occurred (fig. 9).

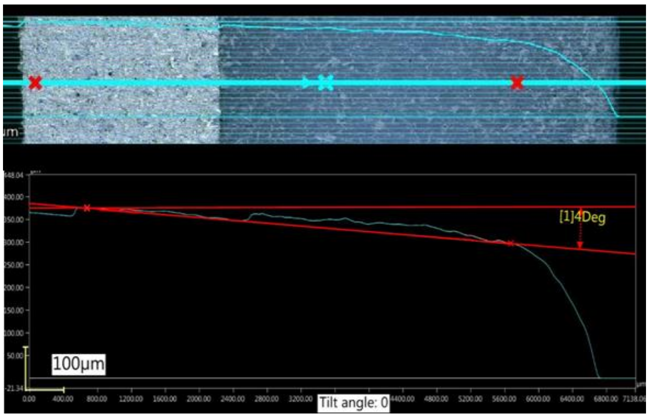

Fig. 9. Angle of cross-section of double-layer structure PA6 polyamide - aluminum alloy 2017A

Conclusions

Based on the analysis and experimental studies, the following conclusions were drawn:

At the time of cutting the structure, there was no delamination in any case. No other damage has occurred in the glue joint zone.

During initial observations, it was noted that the largest defects in the cut surface occurred at feed rate v_f = 1000 mm/min and smaller at feedrate v_f = 500 mm/min. At feed speed v_f = 200 mm/min the quality of the surface obtained was generally good. Sporadically, minimal curved traces appear after processing.

Analyzing the samples using a microscope, the irregularity of the cut surfaces was observed. In most cases, there was a tendency to taper toward the exit.

In two- and three-layered structures, 316L steel - carbon composite and 316L steel - PA6 polyamide - carbon composite, a sharp change in the bevelling angle of the surface formed after cutting was observed. When the abrasive jet enters the 316L steel sample, it narrows, and then, upon reaching the adhesive joint, expands exponentially towards the exit. The bevel angles values increase as the feedrate increases. On the other hand, when the stream feeds on the carbon composite side, this phenomenon does not occur - the plow narrows over the entire thickness of the cut.

In the case of the 2017A aluminum alloy with PA6 polyamide, there is also a change in the chamfer angle resulting from the cut, but not as fast as in the case of 316L and carbon composite. When the cutting process starts on the side of polyamide PA6, this phenomenon does not occur - the slab minimizes.

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The research has confirmed the effectiveness of using a high-pressure water-abrasive jet to cut the spacer structures. Due to properly selected technological parameters, the quality of cut surfaces can be obtained. Also important is the machining strategy, especially when the physical characteristics of the materials used in the spacing structure are significantly different.

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