THE INFLUENCE OF ADHESIVE TYPE AND SURFACE TREATMENT ON THE STRENGTH OF C45 STEEL SHEETS ADHESIVE JOINTS

Wpływ rodzaju kleju i sposobu przygotowania powierzchni na wytrzymałość połączeń klejowych blach ze stali C45

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Abstract: The aim of the article was to present issues related to the determination of the impact of selected technological factors: the method of surface treatment and the type of adhesive on the strength of adhesive joints made of C45 steel sheet. The surfaces of the analyzed steel sheet samples were prepared by processing with four different abrasive papers: P120, P280, P320, P800. The sheet samples were bonded with three different epoxy two-component adhesives: Epidian 57/PAC/100:80, Epidian 6/PAC/100:80 and Epidian 62/PAC/100:80, including one-step cure at room temperature of 24 ± 2°C, with humidity 26 ± 2%. After the curing process, strength tests of the adhesive joints were carried out on the Zwick / Roell 150 testing machine in accordance with the PN-EN 1465 standard. It was noticed, among others, that the preferred surface treatment method was surface treatment with the P280 abrasive tool, after which the adhesive joints showed the highest shear strength.

Keywords: adhesive joints, strength, C45 steel sheet

Streszczenie: Celem artykułu było przedstawienie zagadnień związanych z określeniem wpływu wybranych czynników technologicznych: sposobu przygotowania powierzchni oraz rodzaju kleju na wytrzymałości połączeń klejowych wykonanych z blachy stalowej C45. Powierzchnie analizowanych próbek blachy stalowej zostały przygotowane poprzez obróbkę czterema różnymi papierami ściernymi: P120, P280, P320, P800. Próbki blach zostały sklejone trzema różnymi klejami epoksydowymi dwuskładnikowymi: Epidian 57/PAC/100:80, Epidian 6/PAC/100:80 oraz Epidian 62/PAC/100:80, uwzględniając jednostopniowe utwardzanie w temperaturze pokojowej 24±2°C, przy wilgotności 26±2%. Po procesie utwardzania dokonano prób wytrzymałościowych połączeń klejowych na maszynie wytrzymałościowej Zwick/Roell 150, zgodnie z normą PN-EN 1465. Zauważono m.in., że korzystnym spośród badanych metod przygotowania powierzchni jest przygotowanie powierzchni ściernym narzędziem nasypowym P280, po którym połączenia klejowe wykazały największą wytrzymałość na ścinanie.

Słowa kluczowe: połączenie klejowe, wytrzymałość, blacha stalowa C45

Introduction

There are numerous methods of bonding different elements, e.g. parts of the machinery. They include: bonding with screw joints, welding, riveting, soldering, and pressure welding. It is of high importance to use the methods that ensure obtaining the bonds of the assumed properties without compromising the construction's characteristics, i.e.: dimensions, shape, functionality, usability, reliability, aesthetics, modularity or versatility.

Adhesive joints are one of the most often used bonding methods in various constructions [1, 5] and are categorised as permanent joints. Their most prominent advantages include, among others [5]: lighter weight of the whole construction, the possibility of joining the elements made of both the same and different materials and geometry, less elements used in relation to other types of joints and a uniform stress pattern thanks to the lack of holes on the surface that often occur in case of different joints, e.g. bolted or riveted ones. Apart from numerous advantages, the adhesive joints and the bonding process itself also have some disadvantages that need to be taken into consideration, e.g.: the ageing process caused by, among others, changeable weather conditions that have considerable negative impact on the adhesive joint's strength [2, 3, 8] or the necessity of using various, often time-consuming, surface treatment methods in case of some materials [4, 11, 14]. As a result, the elements' bonding method may need to be reanalysed or even changed.

Numerous factors have impact on the bonding process and the properties of the adhesive joints. They include: constructional, technological, material and exploitation ones, which are subject to the experimental tests, whose results are presented in numerous works [3, 6, 7, 12, 13].

Taking into consideration the characteristics of this method, as well as the factors impacting the obtained joints' strength, it is necessary to strive for such an adhesive joint that will be characterised by the appropriate strength and resistance to the exploitation factors. It is determined by, among others, the technological factors that, in case of the present article, include the adhesive type and the joined materials' surface treatment.

Experimental test method

The adhesive joints made of the C45 steel sheets were used to conduct the experimental tests. The surfaces of the analysed samples were prepared by processing with use of four different abrasive paper types. Then the samples were bonded with use of three different adhesives. The strength tests of the adhesive joints were carried out.

The joints used in the experimental tests were the single-lap adhesive joints made of C45 steel sheet. Figure 1 shows shape and dimensions of the analysed joint.

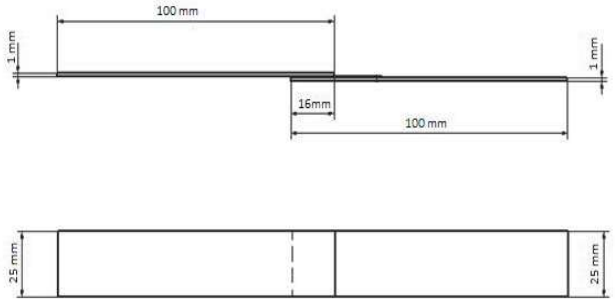

Fig. 1. A single-lap adhesive joint made of C45 steel
Rys. 1. Połączenie klejowe jednozakładkowe blachy ze stali C45

The surfaces of the analysed samples were prepared by mechanical working, specifically by processing with four different abrasive papers: P120, P280, P320 and P800. 30 rotary movements with the abrasive papers of the aforementioned grit sizes were performed on the surface of each sample. After mechanical working the samples were degreased by rubbing-through three times with use of acetone. The drying time after degreasing was 2 minutes.

Three types of two-component epoxy adhesive compounds (epoxy resin and curing agent), presented in Table 1, were used to make the adhesive joints.

The Epidian 57 resin is an epoxy compound obtained by modifying Epidian 5, which is a specially selected saturated polyester resin. Epidian 6 is a multi-use epoxy resin. Epidian 62 is a clear and viscous epoxy resin, modified with an inactive yellowish diluent. After being cured, the compound is of milk-white colour and non-transparent. The aforementioned compounds are used for, among others, making the adhesives for bonding various construction materials, including the steel elements.

Rodzaj żywicy	Rodzaj utwardzacza	Stosunek składników żywica: utwardzacz	Oznaczenie kleju
Epidian 57	PAC	100:80	Epidian 57/PAC/100:80
Epidian 62	PAC	100:80	Epidian 62/PAC/100:80
Epidian 6	PAC	100:80	Epidian 6/PAC/100:80

Table 1. Adhesive compounds
Tabela 1. Kompozycje klejowe

The PAC curing agent is obtained by polycondensation of polyamine with dimers of the fatty acid methyl esters. The curing agent increases the cured compound's elasticity and its impact resistance. However, it also decreases its hardness and resistance to high temperature.

The basic parameters of the adhesive compounds' ingredients were presented in the references [9, 10, 15].

In order to weigh the needed amount of all the adhesive compounds' ingredients, an electronic balance (model OP-2, produced by FAWAG S.A.) with the accuracy of 0.01 g was used. The ingredients were mixed manually with use of a mechanical mixer at the adhesive mixing station. The mixing speed was 460 rpm and the mixing time was 2 minutes. A polymer spatula was used to apply the adhesives mass.

The samples were bonded in the following conditions: the temperature of 24±2°C and the humidity of 26±2%. The adhesive joint's one-step curing process, with use of pressure of 0.18 MPa, was conducted in the same conditions. The strength tests of the adhesive joints were carried out on the Zwick/Roell 150 testing machine in accordance with the DIN PN-EN 1465 [16] standard and with the cross-bar moving at the speed of 5 mm/min.

8 joints were made for each joint variant and adhesive type. In total 96 adhesive joints of the C45 steel sheets were made for the strength analysis.

Experimental tests' results and analysis

When analysing the experimental tests' results, the extreme values for a specific batch of samples were rejected. It was the case when the discrepancies between the results were large. The primary objective was to eliminate the specific values that were too low or too high in relation to other values and that resulted from the faults or defects, which occurred during the bonding process. Then, the arithmetic mean and the standard deviation for each batch of samples were calculated.

Figure 2 shows the comparison of the shear strength test results of the C45 sheet adhesive joints made with use of three different epoxy adhesives in relation to the surface treatment method.

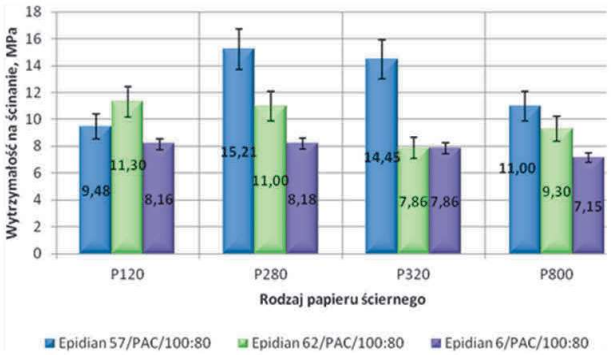

Fig. 2. Comparison of the shear strength test results of the steel sheet adhesive joints made with use of three different epoxy adhesives in relation to the surface treatment method.
Rys. 2. Porównanie wyników wytrzymałości na ścinanie połączeń klejowych blachy stalowej wykonanych za pomocą trzech rodzajów klejów epoksydowych ze względu na sposób przygotowania powierzchni

Based on the shear strength results (Fig. 2), it may be observed that in case of the adhesive joints whose surface was treated with the P120 abrasive paper, the ones that showed the highest shear strength (11.30 MPa) were those made with the Epidian 62/PAC/100:80 epoxy adhesive. The lowest shear strength (8.16 MPa), in turn, was obtained by the adhesive joints made with use of the Epidian 6/PAC/100:80 epoxy adhesive.

When analysing the adhesive joints whose surface was treated with the P280 abrasive paper, the highest shear strength (15.21 MPa) was obtained by those made with the Epidian 57/PAC/100:80 epoxy adhesive. The lowest shear strength (8.18 MPa), in turn, was obtained by the samples made with use of the Epidian 6/PAC/100:80 epoxy adhesive. The shear strength of the adhesive joints made with the Epidian 57/PAC/100:80 epoxy adhesive was higher than the strength of the adhesive joints made with the Epidian 6/PAC/100:80 epoxy adhesive by 46%.

The shear strength tests' results of the single-lap adhesive joints made with three different epoxy adhesives, whose surface was treated with the P320 abrasive paper, showed that the highest shear strength (14.45 MPa) was obtained by those made with the Epidian 57/PAC/100:80 epoxy adhesive. The lowest shear strength (8.18 MPa), in turn, was obtained by the adhesive joints made with use of the Epidian 6/PAC/100:80 epoxy adhesive. The shear strength of the adhesive joints made with the Epidian 6/PAC/100:80 epoxy adhesive was lower than the strength of the adhesive joints made with the Epidian 57/PAC/100:80 epoxy adhesive by 45%.

When analysing the C45 steel adhesive joints, whose surface was treated with the P800 abrasive paper, the highest shear strength (11.00 MPa) was obtained by those made with the Epidian 57/PAC/100:80 epoxy adhesive. The lowest shear shear strength (7.15 MPa), in turn, was obtained by the samples made with use of the Epidian 6/PAC/100:80 epoxy adhesive. The shear strength of the adhesive joints made with use of the Epidian 6/PAC/100:80 epoxy adhesive was lower than the shear strength of the joints showing the highest strength value by 35%.

The adhesive joints made with use of the Epidian 6/PAC/100/80 epoxy adhesive showed that the highest strength of 8.18 MPa was obtained by the joints whose surfaces were treated with a coated abrasive with the P280 grit, whereas the lowest strength was obtained by the joints whose surfaces were treated with the coated abrasive with the P800 grit. When analysing the experimental tests' results, it may be observed that the strength of the joints whose surface was prepared with the coated abrasive with the grit of P120 was lower than the strength of the joints prepared with the coated abrasive with the grit of P280 by only 0.25%. The adhesive joints whose surface was prepared with the abrasive paper P280, in turn, showed the strength 12.6% lower than the joints showing the highest strength.

In case of the joints made with use of the Epidian 57/PAC/100:80 epoxy adhesive, the adhesive joints characterised by the highest shear strength were those whose surfaces were treated with the coated abrasive with the P280 grit and amounted to 15.21 MPa. The lowest strength, in turn, was obtained by the adhesive joints whose surfaces were treated with the coated abrasive with the P800 grit and was equal to 11.00 MPa. The shear strength of the joints whose surface was prepared with the coated abrasive with the grit of P280 was higher than the strength of the joints prepared with the coated abrasive with the grit of P800 by 27.7%.

When comparing the shear strength results of the adhesive joints made with use of the Epidian 62/PAC/100:80 epoxy adhesive, it may be observed that the joints characterised by the highest trength were those whose surfaces were treated with the coated abrasive with the P120 grit and it was equal to 11.3 MPa. The lowest strength, in turn, was obtained by the adhesive joints whose surfaces were treated with the coated abrasive with the P800 grit and was equal to 9.30 MPa. The shear strength of the joints whose surface was prepared with the coated abrasive with the grit of P120 was higher than the strength of the joints prepared with the coated abrasive with the grit of P320 by 30%.

When comparing the experimental tests' results, it may be stated that in case of the surfaces treated with use of the P280, P320 and P800 abrasive papers, higher strength was obtained by the adhesive joints made with the Epidian 57/PAC/100:80 epoxy adhesive,

whereas lower strength values were characteristic for the joints made with the Epidian 6/PAC/100:80 epoxy adhesive. In case of the surface prepared with the P120 abrasive paper, the highest strength was obtained by the joints made with the Epidian 62/PAC/100:80 epoxy adhesive. Based on the graph above, it may be also noticed that in case of each surface treatment method presented herein, the lowest strength was obtained by the adhesive joints made with the Epidian 6/PAC/100:80 epoxy adhesive.

Summary

Based on the experimental tests results described herein it may be concluded that selection of a proper abrasive tool has considerable impact on the joints' strength. The experimental tests' analysis shows that for bonding the construction steel sheets, the best surface treatment method among all the tested ones is surface treatment with use of a coated abrasive with the grit of P280. The adhesive joints that were subject to mechanical processing with the P280 coated abrasive obtained the highest values of shear strength. Also, the P320 coated abrasive was equally effective in terms of surface treatment. Based on the obtained test results it was stated that the surface treatment method by means of mechanical processing with use of a coated abrasive with the grit of P800 is the least effective as the results were not good enough. Moreover, it was observed that among all the epoxy adhesives used in the tests, the most effective one was Epidian 57/PAC/100:80 epoxy adhesive, as most samples made with it obtained the highest shear strength results, regardless of the abrasive paper's grit used during the steel sheets' surface treatment process.

To conclude, it needs to be stated the mechanical processing has massive impact on the strength of the adhesive joints made of steel sheets. As far as the abrasive paper's grit size is concerned, the adhesive joints' strength is higher when using the paper with coarse grit and much lower when using the fine-grit paper. It results in more surface microroughness that enables the adhesive to firmly stick to the surface. However, it is also related to the adhesive type.

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