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ZESPOŁÓW • MASZYN • URZĄDZEŃ

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PRAKTYCZNE ZASTOSOWANIA WYTYCZNYCH NORMY 26000 W SYSTEMACH MONTAŻOWYCH

Jerzy ŁUNARSKI

W poprzednim numerze TiAM zwracaliśmy uwagę na konieczność zmian kryteriów ocenowych przy projektowaniu procesów i systemów montażowych. Wymaga to określonej świadomości proekologicznej wraz z umiejętnością przewidywania i prognozowania skutków podejmowanych projektów, planów, przedsięwzięć i innych działań generujących zmiany istniejących systemów.

Analiza obecnego stanu ważnych systemów (gospodarczych, demograficznych, klimatycznych itp.) wskazuje, że przekroczone zostały granice umożliwiające naturalną rewitalizację i konieczne są aktywne działania na rzecz przywrócenia zdolności rewitalizacyjnych. Wymaga to wielokierunkowych działań, wśród których jednym z ważnych, są działania zmierzające do zapewnienia tzw. zrównoważonego rozwoju we wszystkich sektorach gospodarczych i innych, w tym także w systemach montażowych, mimo iż ich udział w procesach degradacyjnych jest niezbyt znaczący.

W celu ułatwienia podejmowania działań skutecznie przeciwdziałających destrukcyjnym procesom, opracowano szereg wytycznych, norm, przepisów prawa i innych dokumentów, których celem było i jest:

- wskazanie organizacjom sprawdzonych i skutecznych porad dotyczących działań prosocjalnych i etycznych,
- wskazanie sposobów osiągania pożądanych wyników oraz realizacji usprawnień,
- wskazanie sposobów planowania strategii i realizacji biznesu w sposób zwiększający zaufanie interesariuszy do organizacji,
- wskazanie sposobów postępowania zgodnie z przepisami prawa oraz ustaleniami zawartymi w dokumentach,
- sposobów skutecznego zwiększania świadomości pracowników i interesariuszy dotyczących zagadnień proekologicznych i związanych ze społeczną odpowiedzialnością.

Przykładem niektórych ważniejszych opracowań z tego zakresu są:

a. Normy z zakresu zarządzania środowiskowego (np. seria norm ISO 14000 i EMAS III) zawierające wytyczne proekologiczne dla organizacji.
b. Normy z zakresu bezpieczeństwa (np. PN-N-18000) zawierające wytyczne zapewnienia bezpieczeństwa pracy i jego ocen
c. Normy z zakresu zarządzania etycznego (np. seria norm AA1000 opracowana przez londyński Institute of Socjal and Ethical Account Ability)
d. Normy z zakresu kształtowania świadomości obywateli i aspiracji pracowników (np. SA8000 dotycząca zapewnienia bezpieczeństwa socjalnego), wytyczne sporządzania raportów s[społecznych GRI – Globar Reporting Initiative), kodeksy postępowań BSCI (Business Social Compliance Initiative) i in.
e. Opracowana przez IS norma ISO 26000 będąca uogólnieniem i uszczegółowieniem wyżej wymienionych wcześniejszych inicjatyw, mająca na celu zapewnienie zrównowa.ażonego rozwoju. Prezentuje ona współczesną filozofię biznesu, określaną często jako CSR (Corporate Social Responsibility), jest ona interpretowana również jako odpowiedzialność przedsiębiorstw wobec interesariuszy (Company Stakeholder Responsibility)

Wymagania zawarte w normie ISO 26000 nie podlegają certyfikacji i mogą być wybiórczo lub kompleksowo dobrowolnie wprowadzane w systemy zarządzania organizacjami. Wymagania zawarte w tej normie uwzględniają wytyczne zawarte m.in. w takich dokumentach, jak: Deklaracja praw człowieka, Konwencje ONZ, Przepisy ILO, normy międzynarodowe oraz umożliwiają uwzględnianie lokalnych uwarunkowań.

Według tej normy organizacja powinna opracować Politykę zarządzania społeczną odpowiedzialnością ukierunkowaną na aspekty ekologiczne, społeczne i finansowe, która powinna być realizowana według koncepcji PDCA (planowanie – wdrażanie – sprawdzanie – działanie).

Norma podkreśla konieczność przestrzegania i analizowania takich zasad, jak: wpływ podejmowanych działań na gospodarkę, społeczeństwo, środowisko, przejrzystość działań i decyzji, zachowania etyczne, respektowanie przepisów prawa, praw człowieka oraz gwarantowanie norm zachowań.

Rezultatem zalecanego postępowania powinno być zadowolenie pracowników, systematyczny rozwój firmy, generowanie zysków w warunkach zrównoważonego rozwoju. Uzyskiwanie tych korzyści jest pośrednim efektem zrozumienia zasad CSR, stosowania tych zasad w organizacji, zapewnienie drożnych procesów komunikacji wewnętrznej i zewnętrznej, dokonywanie okresowych przeglądów postępu prac z zakresu CSR oraz ocena wyników działań i inicjatyw w tym zakresie.

Wytyczne tej normy mogą być również z powodzeniem stosowane w systemach i procesach montażowych, które są zarządzane przez nadrzędny system naczelnego kierownictwa, wywierający wpływ na systemy montażowe.

Do ważniejszych praktycznych wymagań względem funkcjonowania systemów montażowych, zapewniających doskonalenie ich ekologiczności oraz pośr4ednio wpływających na wyniki zrównoważonego rozwoju, można zaliczyć:

1. Wybór takich rozwiązań technologicznych, organizacyjnych i serwisowych, które zapobiegną powstawaniu nieodwracalnych szkód środowiskowych zapewniając jednocześnie wymaganą efektywność ekonomiczną.
2. Organizacja odpowiedniego systemu szkoleń i podnoszenia kwalifikacji, kompetencji i świadomości ekologicznej pracowników oraz kształtujących ich innowacyjność w rozwiązywaniu pojawiających się problemów
3. Organizacja odpowiedniego systemu rekrutowania świadomych i kompetentnych pracowników posiadających umiejętności dostrzegania zagrożeń środowiskowych oraz wiedzy jak je ograniczać lub eliminować.
4. Organizacja odpowiedniego systemu nadzorowania i eksploatowania systemów montażowych zapewniający eliminację lub ograniczenie stosowalności materiałów nieekologicznych oraz zapewniający trwałość i niezawodność funkcjonowania systemu produkcyjno-montażowego i jego okresową odnowę.
5. Tworzenie odpowiednich systemów umożliwiających gromadzenie, minimalizację, utylizację lub recykling tworzonych odpadów w produkcji montażowej.

W ramach powyższych wytycznych istnieje wiele różnych rozwiązań lokalnych, szczegółowych, innowacyjnych, które w określonym stopniu sprzyjają proekologicznemu doskonaleniu systemów produkcyjno – montażowych. Redakcja TiAM będzie wspierać i popularyzować najlepsze inicjatywy, rozwiązania i zrealizowane projekty z tego zakresu.

PULL-OFF TEST OF ADHESIVE JOINTS BASED ON POLYESTER-GLASS LAMINATE AND ALUMINUM ALLOY

Badanie wytrzymałości na odrywanie połączeń klejowych przygotowanych na bazie laminatu poliestrowo-szklanego i stopu aluminium

Исследование прочности на отрыв клеевых соединений изготовленных из стеклянно-полестрого ламината и сплава алюминего

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A b s t r a c t: Adhesive joints are widely used in various industries to join different materials. They always have to meet specific requirements for joint strength or durability. The article presents the results of research on the problem of joining elements made of aluminum alloy and polymer composite material present in the railway industry. The tested adhesive joints combine EN AW-5754 aluminum alloy (AlMg3) with a polyester-glass laminate. Three types of adhesives were used in the tests: epoxy, methacrylic and cyanoacrylate. Various methods of preparing the base surface and the bonded elements were used. The adhesive bonded surfaces were prepared using sandblasting and degreasing, grinding and degreasing as well as only degreasing. The research used a composite made with the use of two different technologies: contact molding and vacuum molding. Comparative tests were also carried out by making adhesive joints of two aluminum surfaces. The aim of the research was to propose a gluing technology to achieve min 15 MPa of the pull-off strength. The tests show that the required strength of the joint can be achieved only for an adhesive joint based on epoxy or methacrylic adhesive when preparing the surface of the base material by sanding and degreasing, grinding and degreasing, or even only degreasing.

K e y w o r d s : Adhesive joints, polyester-glass laminate, aluminum alloy, pull-off strength

S t r e s z c z e n i e: Połączenia klejowe są szeroko stosowane w różnych branżach przemysłowych do łączenia materiałów o odmiennych właściwościach mechanicznych i użytkowych. Zawsze muszą one spełniać określone wymagania w zakresie wytrzymałości czy też trwałości. W artykule zaprezentowano wyniki badań dotyczące problemu łączenia elementów wykonanych ze stopu aluminium i polimerowego materiału kompozytowego występującego w branży kolejowej. Badano połączenia adhezyjne występujące pomiędzy stopem aluminium EN AW-5754 (AlMg3) a laminatem poliestrowo-szklanym. W badaniach zastosowano trzy rodzaje klejów: epoksydowy, metakrylowy i cyjanoakrylowy. Zastosowano również różne sposoby przygotowania powierzchni do klejenia. Powierzchnie klejone przygotowano stosując piaskowanie i odtłuszczanie, szlifowanie i odtłuszczanie oraz odtłuszczanie. W badaniach zastosowano kompozyt wykonany dwoma różnymi technologiami: tzw. technologią na mokro (contact molding) oraz z wykorzystaniem worka próżniowego (vacuum molding). Przeprowadzono również badania porównawcze wykonując połączenia klejowe dwóch powierzchni aluminiowych. Celem badań było zaproponowanie technologii wykonania połączenia tak aby wytrzymałość doraźna połączeń na odrywanie była nie mniejsza niż 15 MPa. Z przeprowadzonych badań wynika, że przyjętą wytrzymałość połączenia można osiągnąć wykorzystując klej epoksydowy lub metakrylowy po przygotowaniu powierzchni materiału bazowego poprzez piaskowanie i odtłuszczanie, szlifowanie i odtłuszczanie lub odtłuszczanie.

S ł o w a k l u c z o w e : Połączenia adhezyjne, laminat poliestrowo-szklany, stop aluminium, wytrzymałość na odrywanie

Introduction

Adhesive joints are becoming more and more popular and they are a particularly attractive method of joining construction materials with different mechanical and functional properties, e.g. metal and composite elements [1, 2]. In work [4] a review of conditions generating the demand for adhesive joints was presented. In construction, adhesive joints are used, for example, to joint composite laminates with steel beams [8]. For joining metal and composite elements, adhesive joints are also used in aircraft constructions [5], in turbine production [10] or in pipe joints [11]. A special solution in which adhesive joints are used is the production of hybrid composites, in which metal layers, e.g. aluminum foils, are alternately joined with a composite material to form a laminate with unique properties [9].

Previous studies of adhesive joints based on polyester-glass laminates and aluminum show that in addition to the identified problems defined for adhesive joints, there are new, associated with limited interlayer strength of the laminates. A non-uniform distribution of stress in the adhesive joints and stress concentration effects at the ends of their overlap cause the pull-off and peeling phenomena not only in the adhesive, but also in the joined composite element. Consequently, as a result of the joint load, not only the joint is damaged, but very often also the composite material as a result of exceeding the adhesive interlayer strength of the laminate. These types of problems do not only occur when joining metal parts [3, 6, 7].

This paper presents the results of experimental tests of adhesive-bonded tensile joints used for joining elements made of aluminum alloy and polymer composite material.

Research problem, assumptions and research goal

The problem considered in this paper concerns the production of adhesive joints for use in the railway industry. The analyzed joints is used in the process of mounting the locomotive lighting housing to the locomotive cabin. The material used in the production of the locomotive body is a polymer composite. The lighting housing is an aluminum element. The problem concerns the selection of appropriate materials and conditions for the production of the adhesive joint to obtain a joint with a minimum pull-off strength of 15 MPa. In the work various types of adhesives (epoxy – EP, methacrylic – MK, cyanoacrylic – CA), various methods of surface preparation (sandblasting and degreasing – PO, grinding and degreasing – SO, degreasing – O) and various methods of producing composite material (so-called wet technique – contact molding and the technique uses vacuum bag technology – vacuum molding) are used. In addition, comparative studies were carried out in which the base material was aluminum alloy. The aim of the study was to determine the pull-off strength of the adhesive joints.

Research plan

The research identified three factors that have a potential impact on the quality of adhesive joints: the materials to be joined, the type of adhesive, the method of preparing the surface of the base material (PP) and the element to be joint (PE). The tested materials are aluminum alloy EN AW-5754 (AlMg3), polyester-glass laminate made by hand technology (laminate A) and polyester-glass laminate made in vacuum technology (laminate B). The curing time for the adhesive bond was

Tab. 1. List of completed experimental tests; PO – Sandblasting and degreasing, SO – Grinding and degreasing, O – Degreasing, EP – Epoxy glue, MK – Methacrylate glue, CA – Cyanoacrylate glue
Tab.1. Lista zrealizowanych testów eksperymentalnych; PO – Piaskowanie i odtłuszczanie, SO – Szlifowanie i odtłuszczanie, O – Odtłuszczanie, EP – klej Epoksydowy, MK – klej Metakrylowy, CA – klej Cyjanoakrylowy

Experiment No	Adhesive	Base material	Preparation of base material surface (BM)	Preparation of stamps surface (PE)	Curing time [hrs.]
E 1	EP	Aluminum	PO	PO	72
E 2	EP	Laminate A	SO	PO	72
E 3	EP	Laminate B	SO	PO	72
E 4	MK	Aluminum	PO	PO	24
E 5	MK	Laminate A	SO	PO	24
E 6	MK	Laminate B	SO	PO	24
E 7	CA	Aluminum	PO	PO	24
E 8	CA	Laminate A	SO	PO	24
E 9	CA	Laminate B	SO	PO	24
E 10	EP	Aluminum	SO	SO	72
E 11	EP	Laminate A	SO	SO	72
E 12	EP	Laminate B	SO	SO	72
E 13	MK	Aluminum	SO	SO	24
E 14	MK	Laminate A	SO	SO	24
E 15	MK	Laminate B	SO	SO	24
E 16	CA	Aluminum	SO	SO	24
E 17	CA	Laminate A	SO	SO	24
E 18	CA	Laminate B	SO	SO	24
E 19	EP	Aluminum	O	O	72
E 20	EP	Laminate A	O	O	72
E 21	EP	Laminate B	O	O	72
E 22	MK	Aluminum	O	O	24
E 23	MK	Laminate A	O	O	24
E 24	MK	Laminate B	O	O	24
E 25	CA	Aluminum	O	O	24
E 26	CA	Laminate A	O	O	24
E 27	CA	Laminate B	O	O	24

Tab. 2. The applied adhesive curing conditions
Tab.2. Zastosowane warunki utwardzania kleju

Adhesive	Temperature [˚C]	Lifetime of adhesive	Stabilization (immobilization) time	Full curing time
Epoxy	23	40 min	4 hrs.	72 hrs.
Methacrylic	23	10 min	20 min	24 hrs.
Cyanoacrylic	23	60 sec	5 min	24 hrs.

24 or 72 hours. 27 experimental tests were carried out (Table 1). In each test, two plates of material in a form of A4 and 10 aluminum stamps bonded to the plates were used, 5 pieces per plate.

Experimental tests were carried out in series of three, which resulted from the number of solutions in the frame of preparing the surface for jointing. The adhesive used in the tests had the same production series.

Specimens preparation

In order to remove impurities, three types of surface preparation for adhesive bonding were used in the tests: degreasing, sandblasting and grinding. Degreasing was carried out immediately before grinding, sandblasting and adhesive processes. The material was degreased with an organic solvent (Isopropanol). After degreasing, the material was allowed to evaporate for 10 minutes. Surface treatment and adhesive application was carried out within 20 minutes after degreasing. Sandblasting was done manually in a pressure sandblaster. Corundum abrasive F46 was used for sandblasting, the jet pressure did not exceed 8 bar. The sandblasting head was held at an angle of 45-60 degrees, the head was moved smoothly and uniformly. Sandblasting time was chosen so as to obtain a matt surface, without gloss or discoloration. Properly processed material has the same tone over the entire surface used. Grinding was done manually with a belt grinder. cross grinded technique was applied. The first grinding was done to remove the surface layer and impurities. The second grinding, transverse to the first, was to remove traces of the previous one and results in obtaining an even surface roughness. Abrasive paper with P60 gradation was used. After machining, the surfaces were washed again with solvent.

Used materials

The applied epoxy adhesive is a two component chemically cured adhesive. The curing process was initiated by mixing two components (resin and hardener) at room temperature. It was a polyaddition adhesive, which means that resin and hardener alternate in the polymer chain of such an adhesive, so it requires a large amount of hardener compared to other adhesives. The second adhesive used was methacrylic adhesive. It is also a two-component chemically cured adhesive. The curing process was initiated by mixing the two components at room temperature. Like the epoxy adhesive, it cured to duromer form and had similar mechanical and performance properties. The difference between these adhesives is due to the mechanism of polymer chain formation. Methacric adhesive belongs to polymerization adhesives. This type of chemical reaction does not require alternating hardener and resin chain order. This adhesive cures more easily and is more tolerant to impurities or improper surface preparation. The last used adhesive, cyanoacrylate adhesive, is a one-component adhesive. The hardener is water in the form of moisture on the surfaces to be joined. The curing process begins when it touches the surface. The recommended relative humidity is between 30 and 60%. This is called instant adhesive cured in a few seconds. A special type of adhesive with a slow curing process was used for the test to extend the lifetime of adhesive. Only the adhesive that has direct contact with moisture cures on the joined surfaces, therefore the maximum joint thickness is 0.2 millimeters. The cured adhesive is in the form of a thermoplastic material – a plastic that is sensitive to temperature, solvents and moisture. The applied adhesive curing conditions are shown in Table 2.

Two laminates were used in the joints. Laminate A is a glass-polyester laminate made by hand (called hand lay-up), which involves manual supersaturation of polyester resin of glass fabrics arranged in the form of intersecting layers. Laminate B is a glass-polyester laminate made by vacuum forming. The method of implementation consists in sucking air from the mold while saturating glass fabrics with resin. This ensures much more accurate resin impregnation, eliminates air bubbles and positively affects the homogeneity of the laminate. In the study A4 panels cut from panels of larger sizes were used. This way, the "edge" part of the material with the largest number of imperfections was eliminated. The panels were coated with gelcoat used to produce the locomotive cabin. In the research aluminum alloy EN AW-5754 (AlMg3) in the form of A4 sheets with a thickness of 2 mm was additionally used.

Conditions for making adhesive joints

The bonding process took place in the adhesive zone prepared in accordance with DIN 6701, the so-called "Clean room". Conditions prevailing during the making of adhesive joints and during the curing of the adhesive were regulated and monitored to ensure their repeatability. Due

Fig. 1. Removing adhesive outflows
Rys. 1. Usuwanie nadmiaru kleju

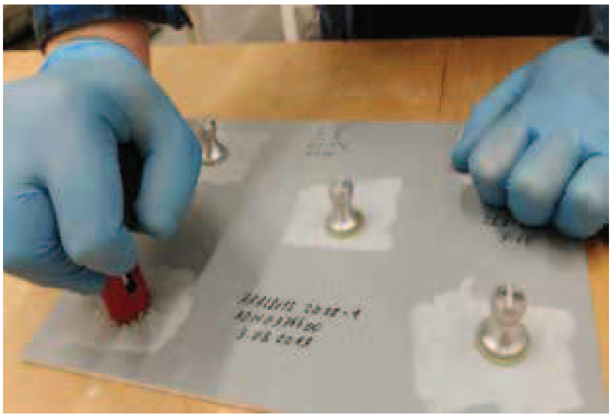


Fig. 2. Pull-off testing
Rys. 2. Zrywanie próbki

to the influence of temperature on the curing time of the adhesive and the final strength of the adhesive joint, the temperature was maintained in the range of 22 to 24 degrees Celsius during the process. The relative humidity in the room ranged from 30 to 60%. All materials used in the study (metals, laminates, adhesives, solvents) were subject to a 24-hour acclimatization process in the adhesive zone. The exception were sandblasted elements, which had to be bonded within 24 hours of sandblasting and were acclimatized before sandblasting. No substances (silicone adhesives, greases, latex gloves, hand protection creams) containing silicone, which is an anti-adhesive agent, did not get into the adhesive area. Powder-free nitrile gloves were used when making adhesive joints.

The method of assessment of pull-off strength of the adhesive joints

The pull-off strength test was carried out with the use of pull-off method, belonging to destructive tests. It allows, among others, to determine the adhesion forces occurring between the joined materials, including pull-off strength. The device used for testing is the PosiTest AT-A Automatic Adhesion Tester. The meter measures the adhesion forces by pull-off a stamp jointed to the material, using a hydraulic actuator and a smoothly increased force. The mechanism of the device is based on the use of ball bearings in the mounting ring, which ensures a perpendicular distribution of forces on the pull-off surface.

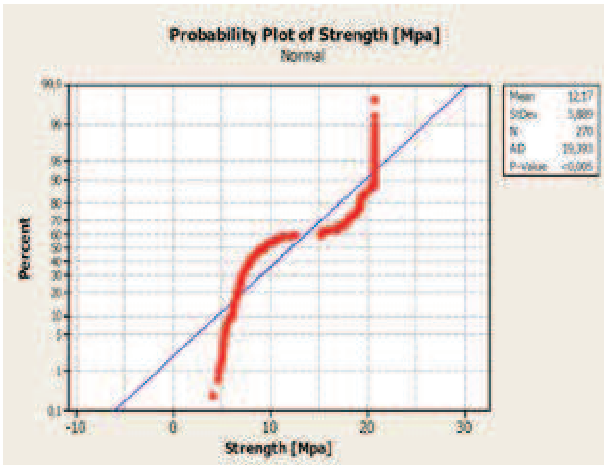
The test used stamps with a diameter of 20 mm dedicated to the measuring range of 0-20 MPa. The device resolution is 0.01 MPa. The force measurement result is given on the electronic display in MPa or psi with an accuracy of ±1%. Before testing, adhesive outflows were removed from the samples with a suitable knife (Fig. 1). Figure 2 shows an example of a sample pull-off testing.

Research results and their analysis

The results of the tests carried out are presented in Table 3 presenting information on the average,

Fig. 3. Adhesive destruction of gelcoat layer – experiment E12
Rys. 3. Zniszczenie adhezyjne warstwy żelkotu – eksperyment E12

Fig. 4. Normality test results of the di
stribution of strength data
Rys. 4. Ocena normalności rozkładu danych dotyczących wy-
trzymałości



Tab. 3. Experimental tests results
Tab. 3. Wyniki badań eksperymentalnych

Exper.	Pull-off strength [MPa]				The type of destruction
	Mean	Max	Min	St. Dev.	
E 1	20.68*	-	-	-	-
E 2	7.11	7.67	6.75	0.31	Cohesive of material
E 3	19.51	20.68	17.16	1.18	Cohesive of material
E 4	20.68*	-	-	-	-
E 5	7.04	7.78	6.32	0.42	Cohesive of material
E 6	18.87	20.68	17.76	1.02	Cohesive of material
E 7	15.39	15.93	15.18	0.22	Adhesive of gelcoat layers
E 8	7.43	7.95	6.97	0.31	Cohesive of material
E 9	11.04	12.58	9.42	0.88	Cohesive of material
E 10	19.32	19.5	19.18	0.12	Adhesive mixed of joint
E 11	6.926	8.03	6.03	0.72	Cohesive of material
E 12	17.98	18.95	16.8	0.78	Cohesive of material
E 13	20.68*	-	-	-	-
E 14	7.53	8.04	6.81	0.50	Cohesive of material
E 15	18.81	19.65	18.03	0.60	Cohesive of material
E 16	8.93	9.52	7.94	0.47	Adhesive of gelcoat layers
E 17	6.71	7.91	6.12	0.53	Cohesive of material
E 18	8.17	8.54	7.56	0.34	Adhesive of gelcoat layers
E 19	5.36	6.26	4.9	0.39	Adhesive mixed of joint
E 20	5.28	6.5	4.14	0.69	Mixed cohesive / adhesive of joint in the ratio 80/20 (plate 1), 70/30 (plate 2)
E 21	5.69	6.58	5.1	0.45	Adhesive mixed of joint
E 22	17.20	17.85	16.08	0.57	Adhesive mixed of joint
E 23	6.84	7.26	6.15	0.31	Cohesive of material
E 24	19.56	20.33	18.93	0.47	Mixed cohesive / adhesive of joint in the ratio 90/10
E 25	10.17	10.71	9.39	0.46	Adhesive mixed of joint
E 26	6.54	7.53	6.22	0.40	Cohesive of material
E 27	9.13	9.94	8.32	0.57	Mixed cohesive / adhesive of joint in the ratio 80/20

maximum and minimum pull-off strength obtained in the experiments, standard deviation and information on the type of joints destruction.

The data presented in Table 3 show that various forms of damage occurred not only in the joint, but also in the composite material (KM) itself, adhesive of gelcoat layer (AP) (Fig. 3), mixed cohesive / adhesive of joints (KAM) and mixed adhesive of joints (AM). The presented results were further analyzed. First, the normality test of the distribution of the obtained strength values was made. From the results obtained (Fig. 4) it can be concluded that the distribution is not normal (P-value <0.05).

Because the data distribution is not normal, the Kruskal-Wallis test was used to identify factors with a statistically justified effect on strength. A confidence level of 95% was adopted. Tests were carried out using the Minitab 16. Based on the obtained P-values, conclusions were drawn regarding which of the following factors have a statistically justified effect on the strength of the adhesive joint: type of adhesive (P-value = 0.000), type of base material (P-value = 0.035), method of preparing the surface of the stamp (P-value = 0.000), surface preparation method for the base material (P-value = 0.000). The tests show that all variables have a statistically justified effect on the obtained strength values. Therefore, further analyzes were carried out to define the nature of this impact. The analyzes were carried out using the Minitab 16 and Statistica 12. First, the analysis of the impact of the type of base material on the strength of the adhesive joint was performed. The obtained results are shown in Fig. 5. In the case of Laminate A, the required strength of at least 15 MPa was not obtained. Therefore, in further analyzes the joints made with the use of this material was not included. Fig. 6 shows the obtained average strength values for various types of adhesives. The highest average strength was obtained for methacrylic glue (MK).

Fig. 5. Joint strength for various base materials (BM)
Rys. 5. Wytrzymałość połączenia dla różnych materiałów bazowych (BM)

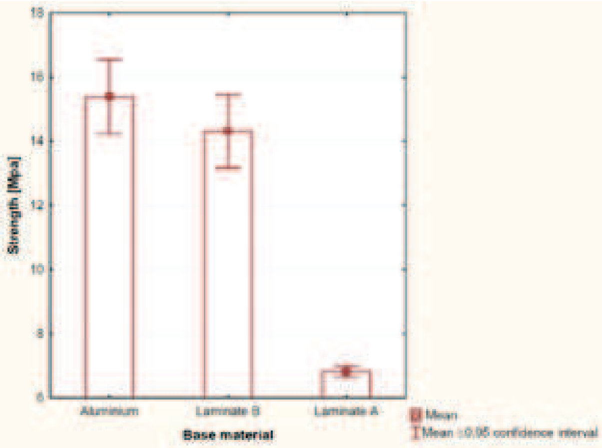


Fig. 6. Joint strength for various types of adhesives
Rys. 6. Wytrzymałość połączenia dla różnych rodzajów klejów

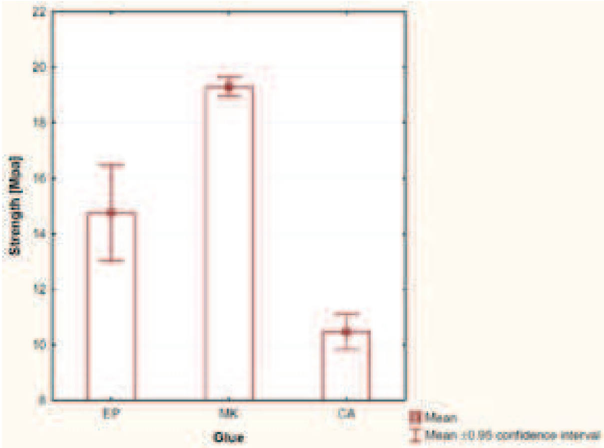


Fig. 7. Joint strength for various methods of surface preparation of base materials (BM)
Rys. 7. Wytrzymałość połączeń dla różnych sposobów przygotowania powierzchni materiałów bazowych (BM)

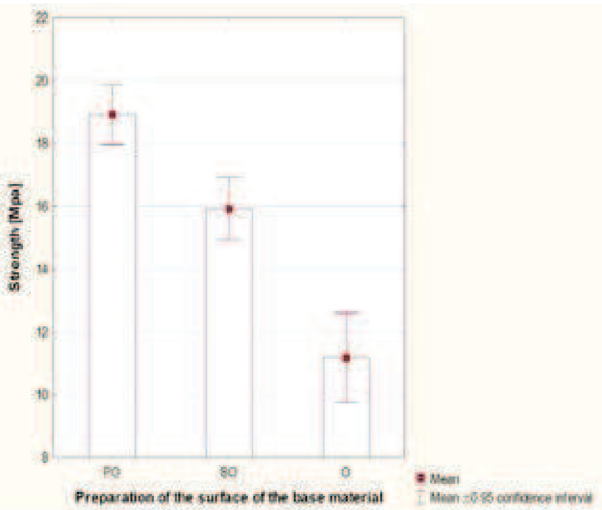


Fig. 8. Joint strength for various methods of surface preparation of joined elements (stamps) (PE)
Rys. 8. Wytrzymałość połączeń dla różnych sposobów przygotowania powierzchni stempli (PE)

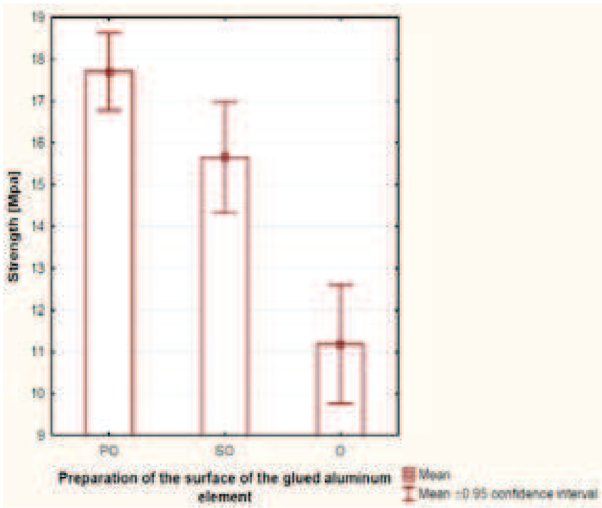


Fig. 9. Joint strength for various adhesives and base materials
Rys. 9. Wytrzymałość połączeń dla różnych klejów oraz materiałów bazowych

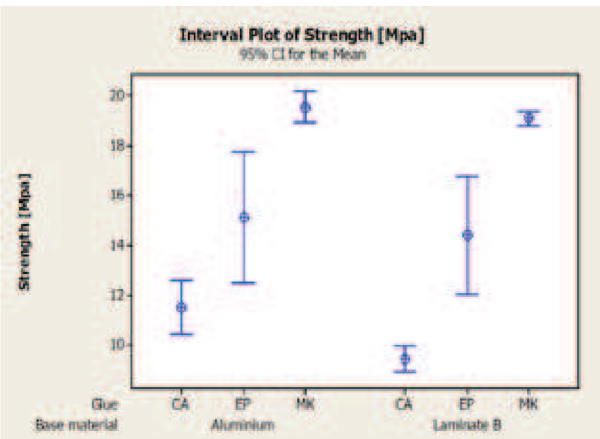
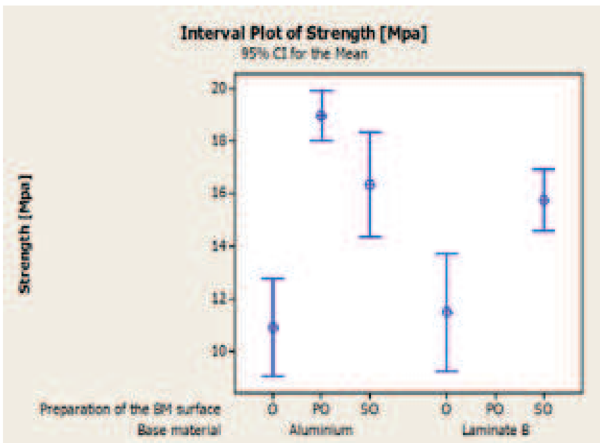


Fig. 10. Joint strength for different ways of the base material surface preparation and various base materials
Rys. 10. Wytrzymałość połączeń dla różnych sposobów przygotowania powierzchni materiału bazowego oraz różnych materiałów bazowych



Tab. 4. List of adhesive joints meeting the condition that strength > 15 MPa
Tab. 4. Wykaz połączeń klejowych spełniających warunek, że wytrzymałość > 15 MPa

Experiment No	Adhesive	Base material	Preparation of base material surface (BM)	Preparation of stamps surface (PE)	Curing time [hrs.]	Mean strength [MPa]
E 10	EP	Aluminium	SO	SO	72	19,32
E 22	MK	Aluminium	O	O	24	17,20
E 7	CA	Aluminium	PO	PO	24	15,39
E 3	EP	Laminat B	SO	PO	72	19,51
E 12	EP	Laminat B	SO	SO	72	17,98
E 24	MK	Laminat B	O	O	24	19,56
E 6	MK	Laminat B	SO	PO	24	18,87
E 15	MK	Laminat B	SO	SO	24	18,81

In terms of the base surface preparation method, the best results were obtained for surfaces after sandblasting and degreasing (PO) (Fig. 7). All adhesive joints in which the surface of the base material was subjected to sandblasting and degreasing met the assumed condition. Assessing the method of preparation of the surface of the adherent element (stamp), the best results were also obtained for surfaces after sandblasting and degreasing (PO) (Fig. 8), although the assumed strength of joints was obtained for all types of preparation of the surface of the adhesive elements.

The strength for various adhesives as well as different ways of base material surface preparation for different base materials are presented in Figure 9 and Figure 10. The best results were obtained for Laminate B when using methacrylic adhesive and when grinding and degreasing of the glued surfaces were applied.

However, because the main purpose of this work was to indicate the conditions for preparing joints ensuring obtaining a pull-off strength of at least 15 MPa, an analysis of the results of individual experiments was conducted and Table 4 presents a list of tests in which this condition was met.

Summary

Based on the tests carried out, it can be concluded that the strength of the adhesive joint at a level of min 15 MPa was achieved only for Laminate B made using a vacuum bag technology. The required pull-off strength can already be achieved by only degreasing the base material surface and the adherent element (stamp), provided however that methacrylic adhesive is used. From the point of view of the labor consumption of the production process, using methacrylic adhesive, which does not require a complex process of preparing the surface for bonding, is justified. In solutions where methacrylic adhesive was used, grinding and sanding of the surface even deteriorated the pull-off strength of the joints.

In the destructive tests of adhesion of composite materials, there may be a problem of degradation not only of joints but also of the material being joined. This is because very often the adhesive strength of protective layers of composite materials, e.g. gelcoat, is less than the adhesive strength of an adhesive joint. Therefore, during the process of preparing the surface for bonding, it is necessary to consider the need to extend the preparatory procedure by mechanical removal of the protective layer – as in the case of adhesive bonding metal elements, the varnish layer is removed.

The suitability of using methacrylic adhesive in the process of mounting the locomotive lighting housing to its cabin should be verified in durability tests. In the case of adhesive joints, the temporary strength of the joint is an important parameter, but taking into account the aging processes occurring in structural adhesives, temporary tests are very often supplemented with durability tests.

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PRELIMINARY EXAMINATIONS OF IMPACT STRENGTH OF ADHESIVE LAP JOINTS

Badania wstępne udarności połączeń klejowych zakładkowych

Начальные исследования ударности нахлестковых клеевых соединений

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Abstract: The research into the impact strength of adhesive joints has been carried out since the 1980s, however, so far no universal method has been developed so as to ensure obtaining useful results. The article presents the authors' own methodology of investigating the impact strength of adhesive joints, developed in Polish military universities. The methodology utilizes adhesive lap joint samples as an object of research. The device for conducting the experimental research was a pendulum hammer of the maximum energy equal to 25 J. The tests were conducted on samples, whose elements were made of an aluminium alloy, joined by means of two construction adhesives with significantly different properties (Young's modulus). The test samples were modelled on the samples exploited in the testing of static adhesive joints. As a result of the preliminary investigations, it was found that the proposed methodology can be used to determine the impact strength of adhesive connections. In addition, it was found that there is a clear relationship between adhesive connections and the stiffness of glue which makes the connection.

Keywords: adhesive joint, impact strength, pendulum hammer

Streszczenie: Badania udarności połączeń klejowych są prowadzone od lat 80-tych XX w., jednak dotychczas nie opracowano uniwersalnej metody zapewniającej uzyskiwanie użytecznych wyników. W artykule zaprezentowano autorską, opracowaną w polskich uczelniach wojskowych metodykę udarnościowych badań połączeń klejowych wykorzystującą jako obiekt badań próbki zakładkowe. Jako urządzenie do prowadzenia badań eksperymentalnych zastosowano młot wahadłowy o maksymalnej energii 25 J. Badania realizowano na próbkach, w których elementy wykonane ze stopu aluminium łączono dwoma klejami konstrukcyjnymi o znacznie różniących się właściwościach (module Younga). Próbki do badań wzorowano na próbkach stosowanych w badaniach właściwości statycznych połączeń klejowych. W wyniku przeprowadzonych badań wstępnych stwierdzono, że zaproponowana metodyka może być stosowana do wyznaczania udarności połączeń klejowych. Dodatkowo, potwierdzono wyraźną zależność udarności połączeń klejowych od sztywności kleju tworzącego połączenie.

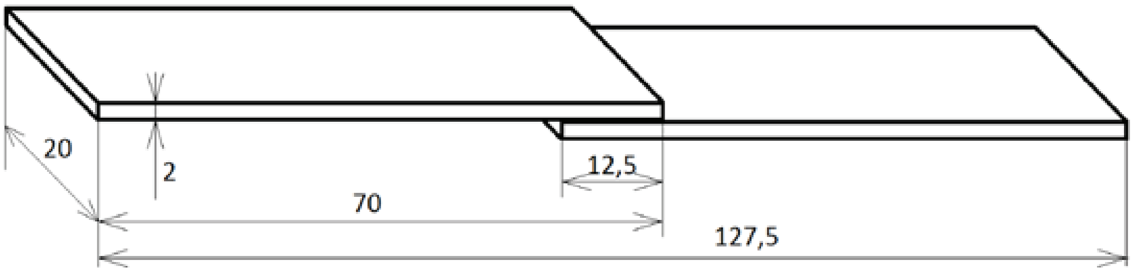
Słowa kluczowe: połączenie klejowe, udarność, młot wahadłowy

Introduction

In the currently designed and used constructions, apart from static and fatigue loads, adhesive joints can also be exposed to impact loading. An example of this type of a construction is modern cars in which numerous elements, such as door panels, car bonnets and a number of elements made with plastics, are manufactured using adhesive bonding technology [7, 9, 11]. In the event of a collision or a car accident, adhesive joints in the construction are frequently impact loaded. In order to properly design and ensure crashworthiness of glued structures, investigations are conducted as well as making estimates of impact strength of the used connections. So far a limited number of procedures has been developed to determine parameters of the impact strength of adhesive joints, taking into account a wide range of application areas, some of which have been adopted as normative procedures. The techniques using pendulum hammers are the most commonly used methods for relatively low speeds of impact loading. By using a pendulum hammer as a test device, it is possible to determine the energy lost during the destruction of the sample, i.e. the impact strength of the connection [10] based on the difference in the pendulum height prior to and after the impact. The majority of examinations are performed using the standard research technique described in PN-ISO 9653 [8]. However, the research conducted with this method is difficult to implement in a repetitive manner due to the fact that it is essential to maintain an extremely accurate behaviour of the sample parameters and the test conditions [1, 5].

Therefore, other research techniques are pursued, e.g. in the available literature it is possible to find descriptions of tests carried out on lap joint samples, in which the joint is sheared during the test [2, 3, 4]. The

Fig. 1. The shape and dimensions of tested samples
Rys. 1. Kształt i wymiary próbki stosowanej w badaniach



method of lap-shear strength is a non-standard method. The technique of conducting research into impact strength is based on the method used in examining glued lap joint samples with regard to static shear strength. The shape, sample dimensions and the manner of applying load have been selected from the above method. The tests are carried out on different devices: pendulum hammers, dropping hammers and devices for performing static strength tests. The manner of mounting the samples in the test device handles and a technique of applying the load vary, depending on the developed technology for the needs of the research. The authors' concept of the implementation of this research has been presented in this article. The subject of this article refers to validation of experimental research. The paper discusses the method of examining lap joint samples, using the test device owned by the Air Force University laboratory which specializes in the examination of adhesive joints.

Fig. 2. Pendulum hammer Julietta
Rys. 2. Młot wahadłowy Julietta

Sample preparation

In order to examine the method of determining the impact strength of adhesive joints, the authors prepared a series of samples made with aluminium alloy 2017A, joined by means of an adhesive composition of Epidian 57 and Z1 hardener (10:1 ratio) or a construction adhesive Loctite 9492. The adhesives were selected due to significant differences in the stiffness of joints produced by them. The Young's modulus of the adhesive Epidian 57/Z1 equals E = 1,800 MPa, and of Loctite 9492 it is E = 6,700 MPa. The number of pieces in each batch was established at 10 by analogy to the examination of impact strength of the materials. Such a large number of pieces in one batch results from a wide discrepancy of the test results. The dimensions of the sample are shown in Fig. 1. The thickness of the adhesive joint in all the test samples equalled 0.1 mm.

In order to prepare the surfaces of the bonded elements, the stream-abrasive treatment (with copper slag as an abrasive medium) was used. The size of the copper slag grain size was 0.8-1.4 mm. The glued elements were subject to treatment until obtaining a uniform surface. During the treatment, the air pressure was approximately 8 kG/cm2 with the nozzle set approximately at a distance of 100 mm from the surface of the treated sample. As a result of the conducted surface treatment, the authors obtained surfaces in which the average arithmetic deviation of the profile from the mean line was Ra = 0.28 μm. Next the prepared profiles were washed in petroleum ether so as to degrease and remove various types of impurities. After this operation, the bonded elements were placed in a laboratory dryer chamber (50° C) for 120 sec to dry their surface in a uniform way. Subsequently, the prepared surfaces were covered with the adhesive as soon as possible. The individual samples were first carefully put together, and after that, mounted in a specially prepared handle. All the samples were loaded with the same grip by means of a screw tightened using the torque of 5 Nm. It was assumed that the value of the tightening torque would make it possible to obtain thin joints of equal thickness. Later, the samples in the

Fig. 3. Intermediate element mounted on tested lap joint sample
Rys. 3. Element pośredniczący zamocowany na próbce zakładkowej

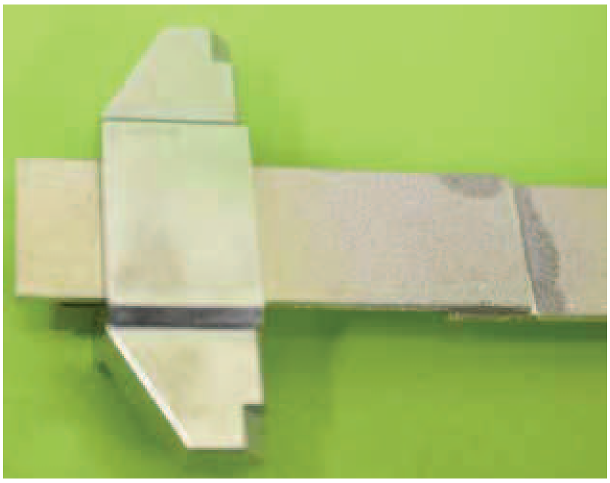
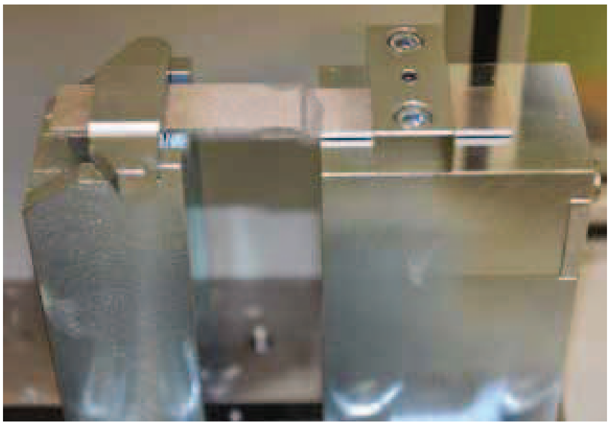


Fig. 4. Lap joint sample fixed in mounting bracket
Rys. 4. Próbka zakładkowa w uchwycie mocującym



grips were placed for 60 minutes in the laboratory drying chamber at a constant temperature of 65°C. After this time, having cooled at room temperature, the samples were stored in order to perform finishing treatment by removing excess joints.

Research methodology

In order to carry out experimental studies aimed at the determination of the impact strength of lap joint connections, the authors exploited the device Julietta for examining the impact strength of adhesive joints (Fig. 2).

The hammer allows conducting research into investigating the impact strength of adhesive block and lap joints with a possibility of using different values of energy and speed of applying a load.

In order to prepare a lap joint sample for the test, an intermediate part is mounted on one of its elements (Fig. 3).

Next the sample is mounted with its other end in a special handle (Fig. 4) fixed to the base of the device. During the test, the dropping pendulum applies the load to the sample, striking the intermediate element. The used manner of fixing two components of the sample allows a secure attachment of the sample during the test, which was confirmed by carrying out validation of the handles in a series of tests, using the maximum energy of the pendulum.

Fig. 5. Impact strength of samples of aluminum alloy 2017A joined with Epidian 57/Z1
Rys. 5. Udarność próbek ze stopu aluminium 2017A przy zastosowaniu kleju Epidian 57/Z1

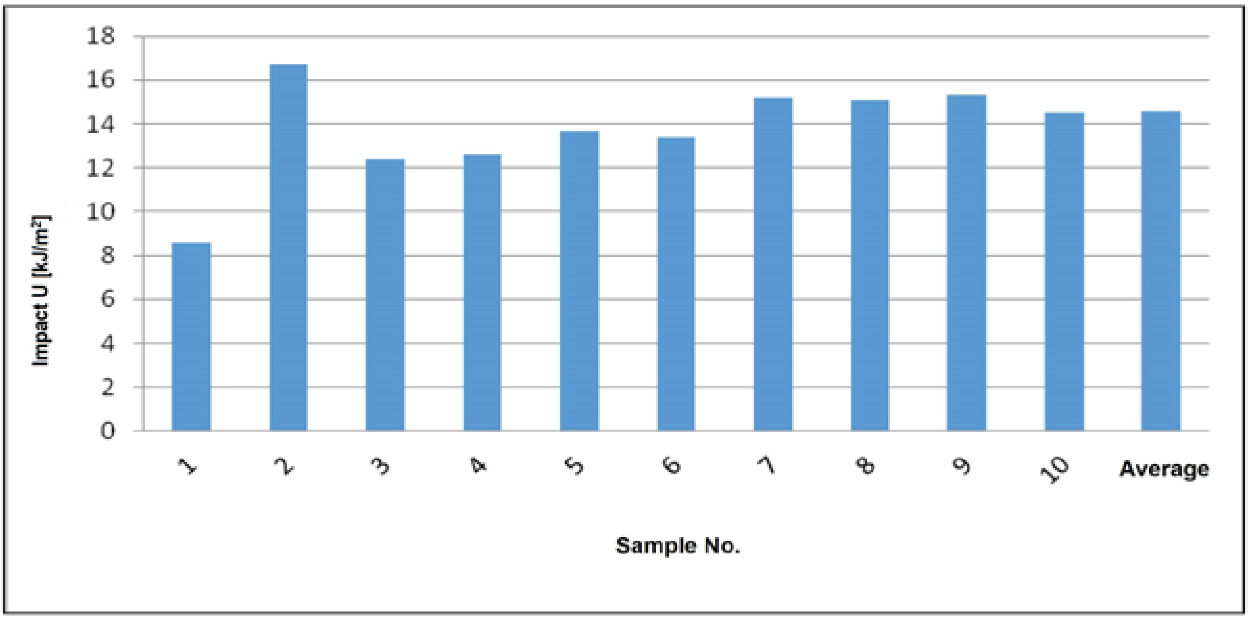
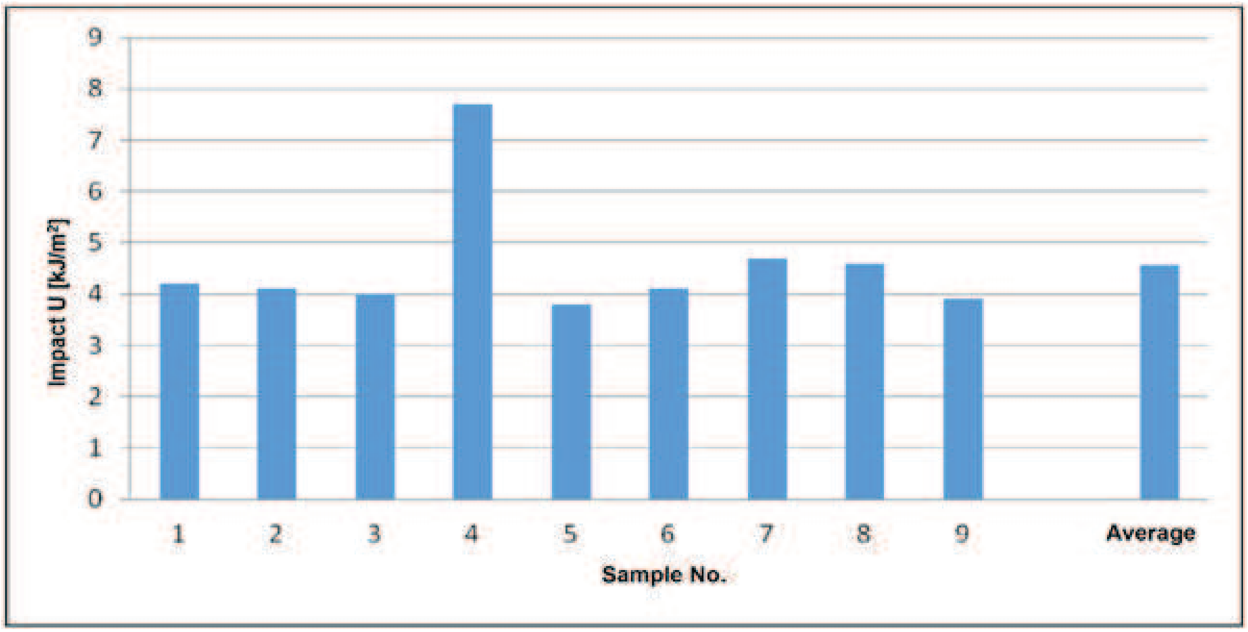


Fig. 6. Impact strength of samples of aluminum alloy 2017A joined with Loctite 9492
Rys. 6. Udarność próbek ze stopu aluminium 2017A przy zastosowaniu kleju Loctite EA 9492



After fixing the sample and introducing the examination parameters, the test is conducted. The test is considered successful if the adhesive joint is destroyed in a single stroke.

The examinations involved using a pendulum with a maximum energy possible to obtain, equal to 25 J.

The experimental results for samples bonded with the adhesive Epidian 57/Z1 have been shown in Fig. 5.

The results of tests in samples bonded with Loctite EA 9492 have been shown in Fig. 6. One of the prepared samples was destroyed during its fixing in the device in the bracket of the test device, therefore the authors marked the findings for 9 samples.

The experimental results for samples bonded with the adhesive Epidian 57/Z1 are characterised by a large discrepancy. In the case of Loctite 9492, the dispersion of results is much smaller.

For the samples bonded with a more flexible adhesive (Epidian 57/Z1), the average impact strength was equal to 14.53 ± 2.63 kJ/m 2, while for the samples bonded with Loctite 9492 the average impact strength was significantly lower and equalled 4.57 ± 0.91 kJ/m 2.

Conclusions

1. There is a possibility of testing lap joint strength in adhesive connections on pendulum hammers, after adjusting these devices to testing lap joint samples. The results of such investigations are characterized by lower spreads compared to samples obtained on block samples, which is a crucial argument in favour of the proposed research methodology.
2. The connections made with an adhesive of a lower Young's modulus are characterised by higher impact strength, which is consistent with the results of earlier research in which block samples were used [6].
3. When executing impact strength research, it is necessary to take into account the fact that that the recorded energy is greater than the energy of joint destruction, since some of it is connected with the energy of deformation of the test stand elements. The numerical calculations also show that for the load speed of approximately 3 m/s, there are distinct wave effects.
4. In further examinations, it is necessary to compare the results of impact strength of adhesive joints, both block and lap ones, with the same joint surface, examined on the same test device.

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THE STRENGTH OF POLYMER MATERIALS'ADHESIVE JOINTS, APPLIED IN THE AUTOMOTIVE INDUSTRY

Wytrzymałość połączeń klejowych tworzyw polimerowych stosowanych w przemyśle motoryzacyjnym

Прочность клеевых соединений полимерных материалов применяемых в автомобильной промышленности

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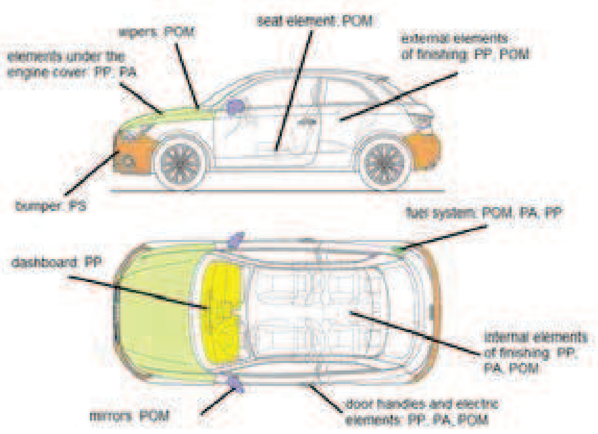
Abstract: The article describes the shear strength and statistical analysis of adhesive joints of four polymers used in the automotive industry, i.e. polypropylene, polystyrene, polyamide and polyacetal. Adhesive joints were prepared using two types of epoxy adhesive: Epidian 57/IDA/100:50 and Epidian 6/TFF/100:27. Surfaces of bonded materials prior to the bonding process were prepared using sandpaper P120, and then to remove impurities formed after mechanical treatment, the surface of polymer materials was degreased with acetone. The adhesive joints after the curing process were subjected to a strength test on the Zwick/Roell 150 strength machine in accordance with the PN-EN 1465 standard. The STATISTICA program was used for statistical analysis of the results of the strength tests. Parameters of descriptive statistics were determined, normality of distribution was determined and statistical tests of strength parameters were carried out. It was noted, among other things, that the greatest shear strength was obtained by adhesive joints of HIPS 425N polystyrene bonded Epidian 6/IDA/100:50 epoxy adhesive. However, the smallest shear strength was characterized by the adhesive joints made of Tarnamid T-27 polyamide bonded with Epidian 6/TFF/100:27 adhesive, which amounted to about 30% of the highest strength value obtained.
Keywords: adhesive joints, strength, polymer materials

Streszczenie: W artykule opisano badanie wytrzymałości oraz analizę statystyczną wyników pomiarów wytrzymałości na ścinanie połączeń klejowych czterech polimerów stosowanych w przemyśle motoryzacyjnym, polipropylenu, polistyrenu, poliamidu oraz poliacetalu. Połączenia klejowe przygotowano za pomocą dwóch rodzajów klejów epoksydowych: Epidian 57/IDA/100:50 oraz Epidian 6/TFF/100:27. Powierzchnie łączonych materiałów przed procesem klejenia zostały przygotowane za pomocą papieru ściernego o gradacji P120, a następnie w celu usunięcia zanieczyszczeń powstałych po obróbce mechanicznej, powierzchnia tworzyw polimerowych została odtłuszczona acetonem. Połączenia klejowe po procesie utwardzenia poddano badaniom wytrzymałościowym na maszynie wytrzymałościowej Zwick/Roell 150, zgodnie z normą PN-EN 1465. Do analizy statystycznej rezultatów badań wytrzymałościowych, wykorzystano program STATISTICA. Wyznaczono parametry statystyki opisowej, określono normalność rozkładu oraz przeprowadzono testy statystyczne badanych parametrów wytrzymałościowych. Zauważono m.in., że największą wytrzymałość na ścinanie uzyskały połączenia klejowe polistyrenu HIPS 425N, wykonane klejem Epidian 6/IDA/100:50. Natomiast najmniejszą wytrzymałością charakteryzowały się połączenia klejowe wykonane z poliamidu Tarnamid T-27, klejone klejem Epidian 6/TFF/100: 27, która stanowi około 30% największej otrzymanej wartości wytrzymałości.
Słowa kluczowe: połączenie klejowe, wytrzymałość, tworzywa polimerowe

Introduction

Since the beginning of its existence, the automotive industry has been recognized by the engineers as one of the main branches of the global industry due to the possibilities which may offered in respect of development of construction, technologies and materials. Willingness to obtain newer and better solutions in the field of construction and operation of car has induced a global race of the producers of vehicles. The increasing number of cars and a rise of the level of the ecological awareness was the reason for introduction of legal regulations aimed at the limitation of exhaust emission [1]. To adapt to the legal regulations, many new constructional and technological methods were introduced; they were intended to limit the mass of the vehicle and reduce the fuel consumption; to these ends, inter alia, light materials were used (aluminium alloys, composites and polymers). Reduction of the mass by 10% allows limiting the consumption of fuel by 5-7% [2].

Fig.1. Application of the selected polymers in a car [1. 3]
Rys. 1. Zastosowanie wybranych polimerów w samochodzie [1,3]



Polymers are the example of materials which have a wide application in car vehicles [2, 4, 5]. Fig. 1 shows the element of car which are manufactured with the application of various types of polymers, including those ones used in the studies, discussed in the present paper. Apart from the elements, presented in Fig. 1, there are many smaller or greater car parts, produced from other polymers such as PVC or ABS (acrylonitrile butadiene styrene) [2]. Polymer elements are often connected using gluing technology [6-8] because gluing allows, inter alia, joining different constructional elements with different physical properties [9]. Such necessity occurs during assembly of different car parts. Additionally, it is an effective method for connecting materials of such type due to aspect of joint tightness what, in the case of car, is very important [10].

Strength is one of the specific parameters of the adhesive joint. The value of adhesive joint is affected by many factors, classified as follows [6, 11]:

- Constructional – size of joint, dimensions and shape of joint, the way of its loading;
- Technological – preparation of surface of the elements to be joined, choice of adhesive, preparation of adhesive mass, conditions of performing and hardening of adhesive joint (time, temperature, humidity, stress, storage conditions;
- Material – surface structure, physical properties of the materials to be joined, state of upper layers;
- Operating – time of the connection work

When assessing the strength of adhesive joint, we consider, inter alia, the direction of external forces' effect, causing the stress in the joint. Hence, due to the greatest stress, the joined samples are subjected to the shear strength tests. To this end, the lapped connection is often applied.

The aim of the work was to examine the strength of adhesive joints of the selected polymer materials which have the application in the automotive industry. To perform the adhesive joints, two different glue combinations, based on epoxy resins, were used. The paper contains the run of the tests and description of the shear strength measurements of the performed adhesive joints and statistical analysis of the obtained values, using STATISTICA program [12 – 14].

Methodology

Description of the materials to be joined

To perform the adhesive joints, the samples of the following polymer materials were utilized:

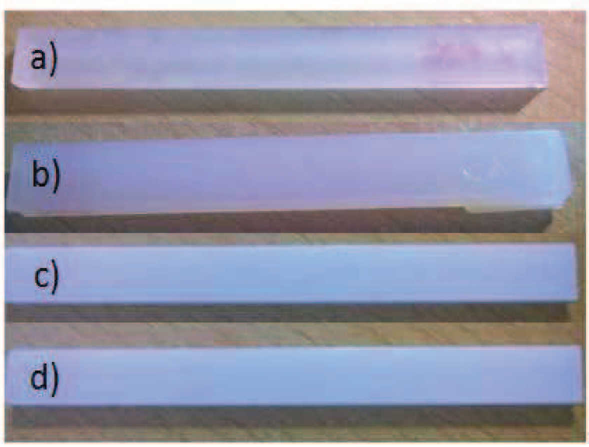
- PP – polypropylene (Malen P),
- PS – polystyrene (Tarnamid T-27),
- PA – Polyamide (Tarnoform T-300 Nat),
- POM – Polyacetal (HOPS 425N).

The test samples were obtained as a result of injection of the tested materials and were characterized by unchangeable dimensions, being the mapping of the shape and size of the sockets of the applied injection form. Each polymer sample, as visible in Fig. 2, had the following dimensions: length – 100 ±1 mm, width – 10±0.5 mm and thickness – 4±0.2 mm.

The conditions for performance of adhesive joint

The preparation of the surface was conducted prior to the performance of the adhesive joints. To these ends, the sandpaper P120 was used; 20 circular motions were carried out, obtaining the unidirectional structure. Then, to remove the impurities formed after the mechanical treatment, the surface of the polymer materials was degreased with acetone [4].

Fig.2. Sample of polymers: a) polypropylene, b) polyamide c) polyacetal
Rys. 2. Próbki wykonane z tworzyw: a) polipropylenu, b) poliamidu, c) poliacetalu, d) polistyrenu



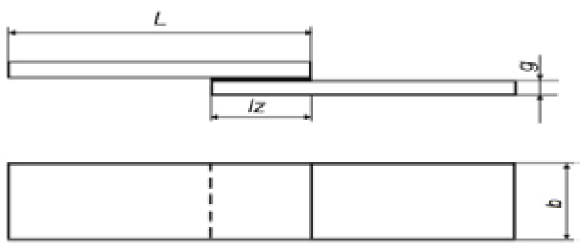
Tab. 1. Summary of the dimensions of adhesive joints
Tab. 1. Zestawienie wymiarów spoin klejowych

Polymer		Length of adhesive joint [mm]	Thickness of adhesive joint [mm]	Surface of bonded area [mm2]
PP	$\bar{X}$	18,76	0,12	187,73
	σ	1,63	0,05	16,35
PS	$\bar{X}$	18,29	0,23	182,82
	σ	1,78	0,22	17,79
PA	$\bar{X}$	17,40	0,41	173,81
	σ	1,34	0,14	13,36
POM	$\bar{X}$	15,42	0,12	154,00
	σ	0,59	0,15	5,82

$\bar{X}$ – mean value
σ – standard deviation

To perform the bonding process, 2 types of epoxy adhesives were used. The first glue was the composition of epoxy resin Epidian 6 and the hardener IDA, mixed in ratio 100:50 (Epidian 6/IDA/100:50). The mentioned type of adhesive was utilized when bonding the samples of propylene and polystyrene. The second composition included mixture of epoxy resin Epidian 6 and the hardener TFF, at ratio 100:27 (Epidian 6/TFF/100:27). The mentioned type of adhesive was used in joining polyamide and polyacetal.

Fig. 3. Scheme of a single overlap adhesive joint
Rys. 3. Schemat połączenia klejowego jednozakładkowego



Scheme of adhesive joint and strength tests

To perform the experimental tests, 48 samples made from 4 polymer materials were prepared; 24 adhesive joints were performed. The samples were divided into two groups, depending on the used adhesive. The real length of the overlaps is given in Tab. 1. The scheme of a single overlap adhesive joint is presented in Fig.3 and Fig.4 shows the example of adhesive joint of polyacetal.

The length of the adhesive joint is different only for polyacetal and is equal to 15.42 mm. In the case of the remaining materials, the discussed length of the joint is found on the level of 18 mm.

During the bonding process, the ambient temperature was equal to 22oC ±2oC and humidity 23%±2%. The performed joints were hardened in cold for 7 days under the same conditions as during the bonding process, under loading of ca. 10 N. After the mentioned period, the samples were subjected to destructive tests in Zwick/Roel Z 150 strength machine in accordance with the standard PN-EN 1465 [15].

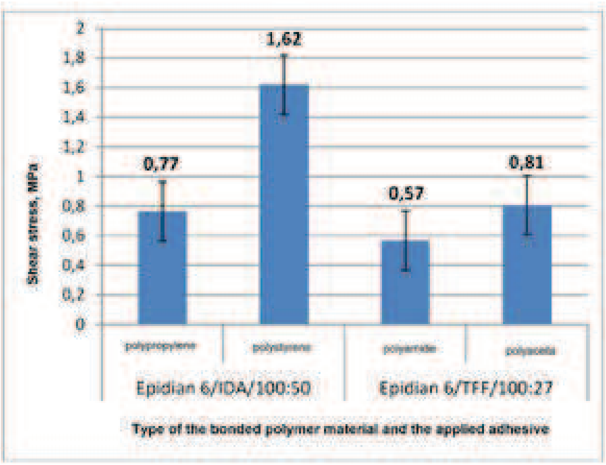
The obtained results of the strength tests were subjected to statistical analysis, using STATISTICA program.

Fig. 4. The example of adhesive joint made of polyacetal HIPS 425N, using composition of adhesive Epidian 6/TFF/100:27
Rys. 4. Przykładowe połączenie klejowe wykonane z poliacetalu HIPS 425N przy zastosowaniu kompozycji klejowej Epidian 6/TFF/100:27

Tab. 2. Summary of the parameters of the strength of adhesive joints
Tab. 2. Zestawienie parametrów statystyki opisowej wytrzymałości połączeń klejowych

Polymer	Parameters of descriptive statistics								
	Number of samples	Mean	Median	Mode	Mode size	Range	Variance	Stand. dev.	Skewness	Kurtosis
PP	6	0,765	0,72	Multiple	1	0,5900	0,0382	0,1954	0,6990	-0,9237
PS	6	1,620	1,60	Multiple	1	0,9400	0,0139	0,1180	0,2510	-2,5222
PA	6	0,5667	0,5700	Multiple	1	0,2100	0,0064	0,0797	-0,3503	-1,2570
POM	3	0,8067	0,7000	Multiple	1	0,6400	0,1109	0,3331	1,2933	-

Fig. 5. Strength of the adhesive joints of polymer materials
Rys. 5. Wytrzymałość połączeń klejowych polimerów



The results of the tests

The results of the parameters of descriptive statistics

The parameters of the descriptive statistics of the selected polymer materials are found in Tab.2.

Six joints for each material to be bonded were performed. In the case of adhesive joint of polyacetal, 3 unsuccessful samples of destructive tests on adhesive joints were discarded. The rejection of the results of the part of adhesive joints of polyacetal is caused by obtaining the results of inconsiderable strength, the value of which was found below 0.10 MPa. The remaining obtained values of adhesive joints have been approved. When analysing the results given in Tab. 2, we may notice the absence of kurtosis for the adhesive joints of polyacetal. It is caused by the size of the test. To obtain the result of kurtosis, the number size of the trial should amount to minimum 4.

Summary of the results of the strength tests

The comparison of the obtained mean results of the destructive force of the tested adhesive joints of polymer materials is shown in Fig. 5. The diagram is divided according to the adhesive applied.

It can be seen from the diagram, showing the strength of adhesive joints that the highest strength value was obtained by the adhesive joint of polystyrene. In the above mentioned bonding, the highest standard deviation was also found. From among the examined joints, in respect of the type of the adhesive used, the highest value of the strength was recorded in the case of polystyrene. Any of the destructive tests for the mentioned joint has not been discarded; however, the adhesive joint of polystyrene revealed the highest standard deviation. Fig. 5 shows a visible distribution of strength values for the discussed adhesive joint. When comparing all obtained strength

Tab. 3. The results of the test, checking a normal distribution, using Shapiro-Wilk test
Tab. 3. Wyniki testu sprawdzające rozkład normalny wykorzystując test Shapiro-Wilka

Assumptions	H_0: The tested sample has a normal distribution		
	H_1: The tested sample has not a normal distribution		
	α=0,05		
Polimer	W	P	Result
PP	0,886	0,298	p>α, no basis for rejection of H_0
PS	0,862	0,195	p>α, no basis for rejection of H_0
PA	0,937	0,64	p>α, no basis for rejection of H_0
POM	0,920	0,453	p>α, no basis for rejection of H_0

Normal value

Fig. 6. Histogram of the strength (a) and diagram of a normality of distribution (b) of adhesive joints of propylene
Rys. 6. Histogram wytrzymałości (a) oraz wykres rozkładu normalności (b) połączeń klejowych polipropylenu

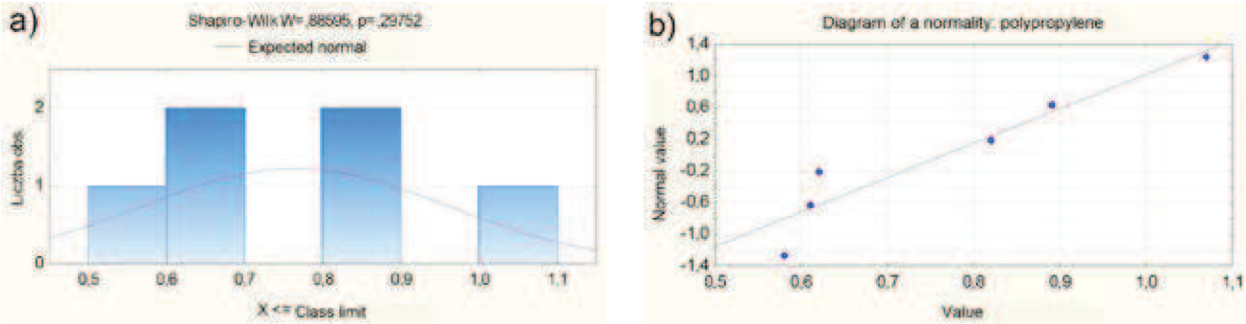
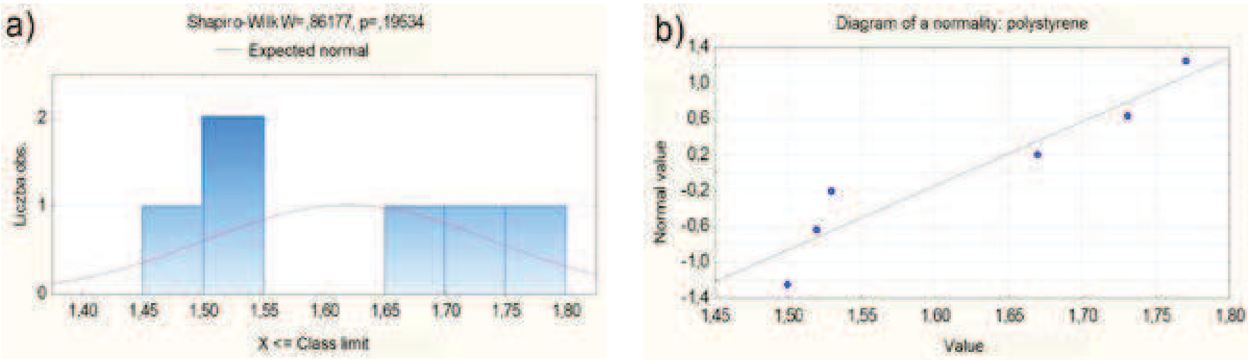


Fig. 7. Histogram of the strength (a) and diagram of the normality of distribution (b) of adhesive joints of polystyrene
Rys. 7. Histogram wytrzymałości (a) oraz wykres rozkładu normalności (b) połączeń klejowych polistyrenu



Tab. 4. The comparative statistics of polymer materials, using t-student test for independent samples
Tab. 4. Statystyka porównawcza polimerów wykorzystująca test t-studenta dla prób niezależnych

Samples	Hypothesis	$t_{oread\ out.}$	$T_{calcul.}$	Result
PP-PS	$H_0{:}\ \bar{X}_1 = \bar{X}_2$	-9,17	2,23	-9,17 ϵ (-∞;-2,23> U <2,23;∞) Rejection of hypothesis H_0 $H_0{:}\ \bar{X}_1 \neq \bar{X}_2$
PA-POM	$H_0{:}\ \bar{X}_3 = \bar{X}_4$	-1,13	2,36	-1,13 ∉ (-∞;-2,36>U <2,36;∞) Lack of basis for rejection of hypothesis H_0

values of adhesive joints, we may state that the adhesive joint of polystyrene obtained the highest result.

Statistical analysis of the results of the strength tests

The obtained results of the strength tests of adhesive joints were subjected to the statistical analysis. In Fig. 6-9, the histograms of the strength and diagrams of a normal distribution for the tested adhesive joints of polymer materials were shown. To this end, Shapiro-Wilk test was applied; the mentioned test is destined for checking small populations, being found in the interval of 3-50 of the tested values. The mentioned test is also characterized by a high power of the test [13]. The results of the Shapiro-Wilk test have been given in Tab. 3. They showed that all the samples subjected to the test obtained a normal distribution.

In further analysis, t-student test was applied for independent trials [12] in order to check whether a difference in the number of the samples of adhesive joints had a statistical effect on the comparison of two adhesive joints. The results of the mentioned test are given in Tab. 4.

Fig. 8. Histogram of the strength (a) and diagram of the normality of distribution (b) of adhesive joints of polyamide
Rys. 8. Histogram wytrzymałości (a) oraz wykres rozkładu normalności (b) połączeń klejowych poliamidu

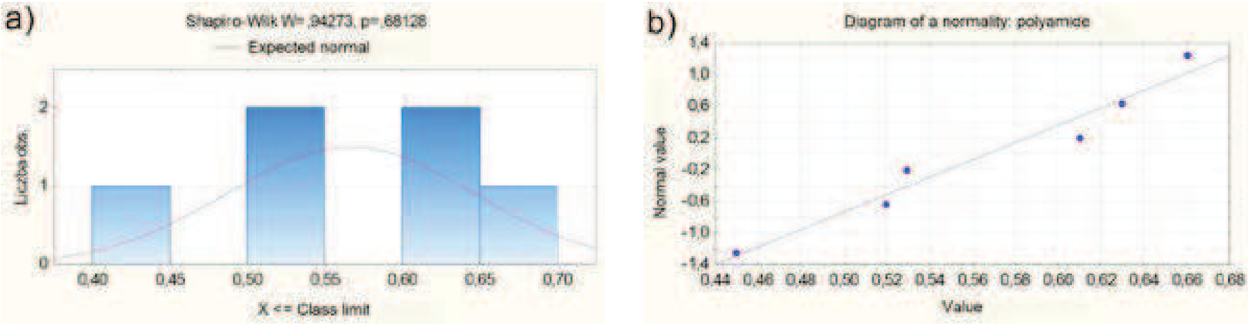
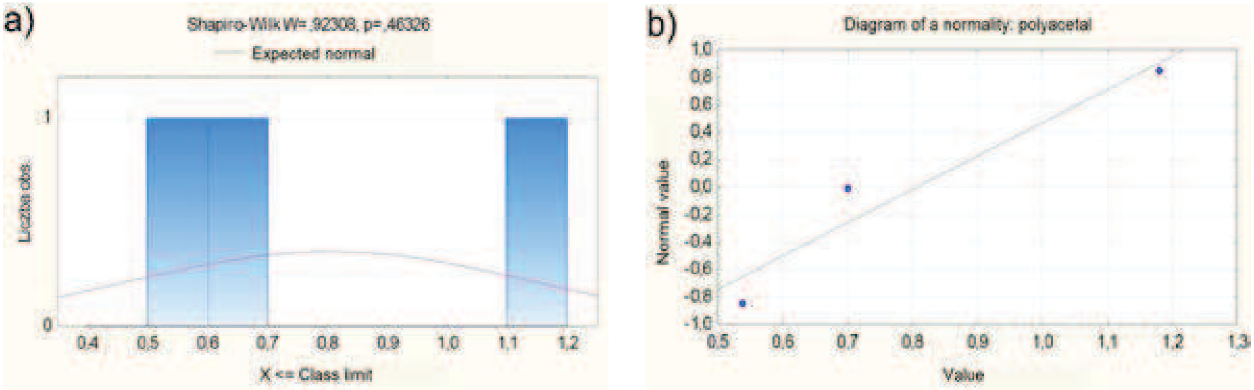


Fig. 9. Histogram of the strength (a) and diagram of the normality of distribution (b) of adhesive joints of polyacetal
Rys. 9. Histogram wytrzymałości (a) oraz wykres rozkładu normalności (b) połączeń klejowych poliacetalu



When analysing the results of the obtained values of the t-student test, comparing the adhesive joints of polymer materials in relation to the applied adhesive composition, it may be stated that only in the case of one of two variants, the basis for rejection of hypothesis Ho does not exist. Variant that meets the mentioned hypothesis is the comparison of the values of adhesive joints where the adhesive composition of epoxy resin Epidian 6 and the hardener TFF were used. In the case of t-student test of adhesive joints with the adhesive consisting of epoxy resin Epidian 6 and the hardener IDA, the hypothesis Ho was rejected. The mean strength results differ each other what can be visible in Fig. 5.

Summary

After conducting the statistical test, the following conclusions may be formulates:

- For the adhesive composition of epoxy resin Epidian 6 and the hardener TFF, the obtained result of statistical analysis of the strength of adhesive joints of polyamide and polyacetal, using t-student test meet the hypothesis on equality of the means;
- When comparing the strength of adhesive joints using Epidian 6/IDA/100:50, it may be observed that they do not meet hypothesis Ho what is an evidence of a high discrepancy of the obtained strengths of the joints;
- The highest strength value was obtained by the adhesive joint of polystyrene; the mentioned values is not equal statistically to the remaining results;
- Epoxy adhesives do not find the application in joining the elements in car vehicles, produced from the examined elements due to the obtained small strength.

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EFFECT OF HOT-DIP GALVANIZATION ON HC 260LA STEEL SCAFFOLDING PLATFORM LOAD CAPACITY

Wpływ technologii cynkowania ogniowego na nośność podestów ruzstowań ze stali HC260LA

Влияние технологии огненного цинкования на работоспособность строительных стелажей из стали HC260A

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Abstract: The goal of the present paper is to examine the influence of hot-dip galvanisation process on mechanical properties of HC260LA steel (yield stress, ultimate stress and elongation) and scaffolding platforms load capacity. The galvanized welded scaffolding platforms manufactured from sheet thickness 1.25 mm were used in the tests. The experiments have shown the increase in load capacity of galvanised scaffolding platforms by 4.76 % compared to the non-galvanised ones.

Keywords: hot-dip galvanisation, HC260LA steel, assembly of scaffolding platforms

Streszczenie: Celem niniejszej pracy są badania wpływu procesu cynkowania ogniowego na zmianę własności mechanicznych stali HC260LA (tj. granicy plastyczności Re, wytrzymałości na rozciąganie Rm i wydłużenia Agt) oraz nośności granicznej stalowych elementów konstrukcyjnych rusztowań. Przedmiotem badań były spawane stalowe podesty rusztowań wykonane z blachy o grubości 1,25 mm. Przeprowadzone badania nośności podestów wykonanych z blach ocynkowanych wykazały nośność wyższą o 4,76% w stosunku do podestów wykonanych z blach nieocynkowanych.

Słowa kluczowe: cynkowanie ogniowe, blacha ze stali HC260LA, montaż podestów rusztowań

Introduction

Hot-dip galvanization is one of the most effective methods for protection of the steel elements of scaffoldings from the corrosion [1]. Owing to galvanization, the durable zinc coatings, resistant to corrosion and to all types of mechanical damages are obtained. The latter property has a great meaning due to the fact that the scaffolding elements are assembled and disassembled many times during their use. The high requirements for the mentioned scaffolding elements in regard to mechanical resistance of the coatings have caused that the different methods of protecting the steel elements of scaffolding e.g. painting. are sporadically employed.

The research in respect of hot-dip galvanization is mainly focused on galvanization technology, quality of coatings and the studies on the impact of material, surface and thickness of galvanized elements on the quality of galvanized coating. In the studies, the problems of the effect of hot-dip galvanization on mechanical properties of materials, from which the galvanized elements are made, have been almost completely omitted. The existing papers are fragmentary and the obtained conclusions are non-univocal. For the examined steels, the authors of a part of the studies did not observe the effect of the hot-dip galvanization on the change in the mechanical properties of the examined steel samples [4]. In some papers, the mentioned effect was found [2, 3]. In paper [3], the results of the tests on the effect of hot-dip galvanization on the mechanical properties of two commonly used steels: St3S and 18G2A, were presented. In the mentioned publication, the performance of the tests with the samples of 8 mm and 10 mm thickness (steel St3S and 18G2A) was documented; in the result of the experiments it was found that the galvanized coatings caused the increase in yield stress and ultimate stress. In paper [2] the results of the effect of hot-dip galvanization on the mechanical properties of low-carbon steel with carbon content 0.045 were presented. In the examined steel, after galvanization, the ultimate stress was decreased and the toughness (fracture energy) – determining the material's resistance to cracking or fracture, corresponding to the energy absorbed during generation of material-destructing fracture.

The changes in mechanical properties of steel after galvanization may have an influence on the resistance of constructional elements, made from the mentioned types of steel. The importance of the discussed problem may be indicated by the results of the resistance tests of the scaffoldings' frames, conducted at the Temporary Construction Research Laboratory of the Institute of Mechanical Construction and Rock Mining. A change in

Tab. 1. Chemical composition of HC260LA steel
Tab. 1. Skład chemiczny stali HC260LA

	C	Mn max	Si	P max	S max	Al min	Ti	N max
	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
HC260LA	≤ 0,10	≤ 0,60	≤ 0,50	≤ 0,025	≤ 0,025	0,015	≤ 0,15	-

the properties of material brings a change in resistance of frames at their loading with the axis forces and bending moment. The described effect of the changes in properties of material has not been practically presented in literature concerning material engineering and steel constructions.

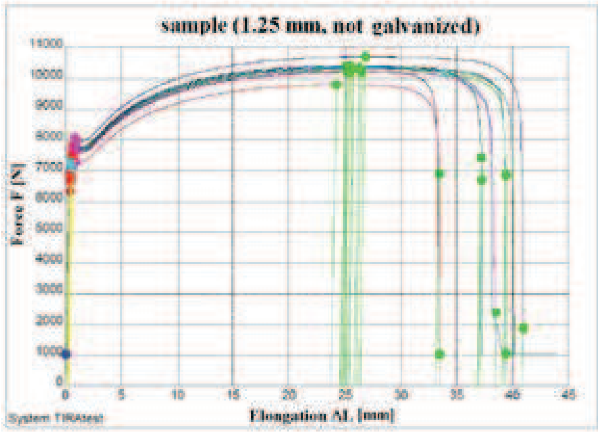
The aim of the paper is to examine the effect of hot-dip galvanization on the mechanical properties of HC260LA steel and on the load capacity of scaffolding platforms, made from the mentioned material. The obtained information may be useful in designing or in evaluation of loading capacity of scaffolding constructions on the grounds of empirical tests and static calculations.

The method of the studies and the results

The studies on the effect of hot-dip galvanization on the resistance properties were conducted firs for the flat samples of HC260LA steel and then, for the element of the scaffolding construction in a form of platform. In tab.1, chemical composition of the examined steel was presented.

In the first part, the tests of the samples cut out from the sheet were performed; then the studies of the produced scaffolding platforms were carried out. The dimensions of the test samples for examination of the resistance properties were selected in accordance with the recommendations of the standard [5]. For the tests, a series of 20 experimental samples was performed. The samples were cut out from the sheet with thickness of b=1.25 mm, using waterjet technology. Fig. 1 shows the tested sample.

Fig.2. Summary chart of tensile tests for non galvanized HC-260LA steel samples (thickness b = 1.25 mm)
Rys. 2. Wykres zbiorczy dla wyników badania wytrzymałościowego nieocynkowanych próbek ze stali HC260LA o grubości b = 1,25 mm.



Initially, the tests of the yield stress, ultimate stress and elongation were carried out. The mentioned values were determined in conformity with the standard [5], performing the static elongation trial. The studies were conducted at the Institute of Mechanical Construction and Rock Mining, in the Temporary Construction Research Laboratory, in strength testing machine TIRA. The results of the tensile tests of the HC260LA steel samples are given in Fig. 2 and the mean values are found in Tab. 2.

Fig. 1. Non galvanized sample – HC260LA steel (thickness 1.25 mm)
Rys. 1. Próbka badawcza nieocynkowana – stal HC260LA (gr. 1,25 mm).

Tab. 2. Experimental results of mechanical properties of HC260LA steel
Tab. 2. Wyniki badań doświadczalnych właściwości mechanicznych stali HC260LA

Type of sample	Yield stress	Ultimate stress	Elongation at yield stress	Total elongation at masimum strength	Total elongation at destruction
	R_e [MPa]	R_m [MPa]	A_e [%]	A_{gt} [%]	A_t [%]
Non galvanized	301,06	402,86	1,09	51,18	74,79
Galvanized	374,80	394,52	-	40,96	61,65
Change of value by	19,67%	-2,11%	-	-24,95%	-21,31%

The second half of the samples was subjected to hot-dip galvanization.

Technology of hot-dip galvanization process during performance of the test samples and platforms:

○ *Degreasing*: bath in degreaser with acid pH to be used in solutions of hydrochloric acid (Degrasan PS);
○ *Digestion*: bath in hydrochloric acid solution:
  • HCl, concentration 40 g/l ÷ 160 g/l,
  • Fe+2, concentration 20g/l ÷ 160 g/l,
  • Temperature of 20oC ÷ 35oC
○ *Washing*; bath in a tub filled with network water at ambient temperature and iron content Fe+2 < 15 g/l;
○ *Flux treatment:* bath in zinc chloride and ammonium chloride solution:
  • Network water,
  • ZnCl2 ≥240 g/l,
  • NH4Cl ≥ 160 g/l.
  • Fe+2 < 15 g/l,
  • Temperature of 25oC ÷ 45oC
○ *Drying*: temp. of 80oC ÷ 100oC, drying time: 15 min. ÷ 40 min.;

○ *Galvanizing*: immersion in zinc bath
  Parameters of galvanization:
  • Composition of zinc bath: 99.8% Zn1, Pb, Al., Ni, Cd, Fe;
  • Temperature of zinc bath: 445OC (real 442oC ÷ 448oC);
  • Immersion time: 2.5 min
  • Method of cooling down: unhampered, at a free air;
  • Time of cooling down: 6 min ÷ 10 min.

The prepared galvanized samples were subjected to resistance tests. After galvanization, the mean thickness of galvanized layer was equal to 52 µm. The curves of elongation for the tested samples are given in Fig. 3. The mean values obtained in the tests on the mechanical properties are presented in Tab. 2.

Tab. 2. contains the comparison of the obtained results of yield stress Re, ultimate stress Rm and

Fig. 3. Summary chart of tensile tests for galvanized HC260LA steel samples.
Rys. 3. Wykres zbiorczy dla wyników badania wytrzymałościowego próbek ocynkowanych ze stali HC260LA

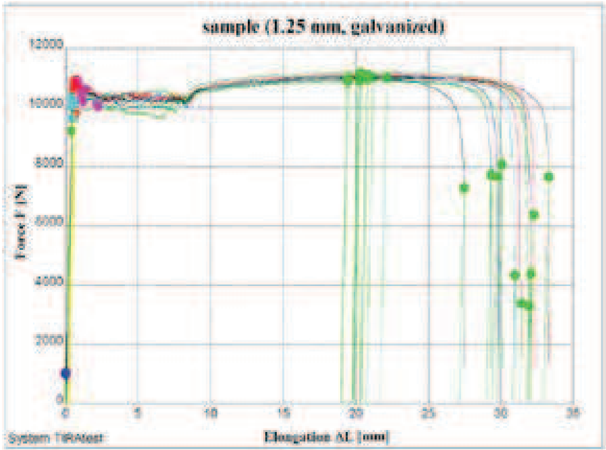


Fig. 4. Galvanize scaffolding platform made from HC260CL steel on the test stand
Rys.4. Ocynkowany podest z blachy stalowej HC260LA na stanowisku badawczym

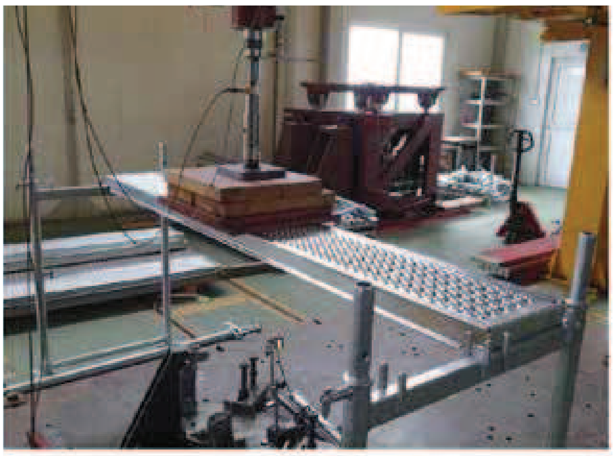
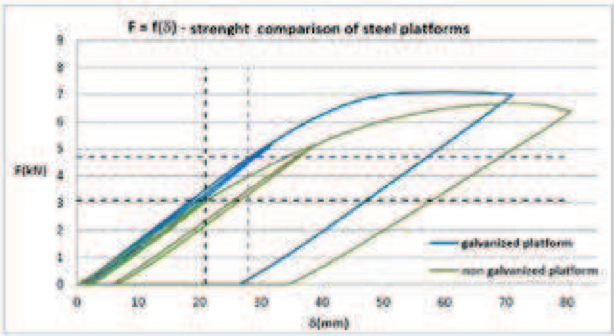


Fig. 5. Test results of galvanized and non galvanized scaffolding platforms strength
Rys.5 . Wyniki badań wytrzymałościowych ocynkowanych i nieocynkowanych podestów rusztowań



Tab.3. Comparison of the test results of scaffolding platforms loading capacity
Tab. 3. Porównanie wyników badań nośności dla podestów rusztowań

Type of platform	load capacity R_{dop} [kN]
non galvanized;	2,80
galvanized	2,94
increase by	4,76%

elongation Agt.

Then, the tests of load capacity of scaffolding platforms [6-8] of the length of 2.5 m, performed from HC260LA steel sheet of thickness b = 1.25, were carried out. Fig.4 presents the loaded scaffolding platform during tensile tests in order to determine its load capacity.

The tests included 5 non galvanized platforms and 5 platforms after hot-dip galvanization. The results of the tests are given in Fig. 5 and Tab. 3.

Conclusions

As a result of the conducted tests, it was found that the hot-dip galvanization process affected the change in the mechanical properties of HC260LA steel. In the case of the tested galvanized samples obtained from HC260LA steel of thickness b = 1.25, the following values were obtained:

– Increase in yield stress Re by 19.67%,
– Decline in value of ultimate stress Rm by 2.11%,
– Decrease in value of elongation Agt by 24.95%.

The studies on the load capacity of steel platforms, made from HC260LA steel sheet of thickness 1.22 mm demonstrated that the platforms after hot-dip galvanization had by ca. 5% higher load capacity as compared to non galvanized platforms. In the diagram illustrating the run of the tests of the load capacity of the platform, being presented in Fig. 5, there is given a very distinct increase in yield stress and decrease in elongation of the platforms after hot-dip galvanization. The demonstrated changes in the parameters of tensile tests of the examined HC260LA steel are most probably the result of the changes in the microstructure of the steel as a result of the temperature impact, occurring during the process of galvanization i.e. temperature of ca. 450oC. On the grounds of the conducted experiments, it is not possible however, to confirm or to exclude the presence of other factors such as time of zinc bath, chemical composition of steel, chemical composition of zinc bath etc. that may have an influence on the mechanical properties.

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GRINDING OF CONICAL SURFACES OF LIGHTING COLUMNS WITH ABRASIVE TOOLS

Szlifowanie powierzchni stożkowych słupów oświetleniowych narzędziami nasypowymi

Шлифовка конических поверхностей светильных колонок абразивным инструментом

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Abstract: In this paper, the methods for grinding conical surfaces of lighting columns were presented. The operation aims to improve the surface quality of the column and prepare it for the application of a varnish layer. The article describes the methods of grinding with embankment tools using leaf blades and endless straps. The characteristics of the methods and the devices that are used to carry out the process are described. Conclusions on improving work efficiency and safety were presented.
Keywords: grinding, lighting poles, embankment tools, leaf blades, endless tapes

Streszczenie: Artykuł przedstawia metody szlifowania powierzchni stożkowych na przykładzie procesu powstawania słupów oświetleniowych. Scharakteryzowano metody szlifowania materiałami nasypowymi z zastosowaniem tarcz listkowych oraz taśm bezkońcowych. Opisano charakterystykę metod oraz przedstawiono urządzenia, które są wykorzystywane do szlifowania słupów oświetleniowych. Opracowano wnioski dotyczące poprawy wydajności oraz bezpieczeństwa pracy.
Słowa kluczowe: szlifowanie, słupy oświetleniowe, materiały nasypowe, tarcze listkowe, taśmy bezkońcowe

Introduction

Manufacturing process of lighting columns made of cone shaped aluminum tubes requires a number of technological operations. One of these operations is shaping a pipe on a special machine that combines two technological treatments, such as rolling and drawing. The semi-finished column to be processed is an aluminum pipe with a suitable composition and a specific hardness. After the rolling process, a pipe with a cone outline is obtained. A lot of surface defects arise on the surface of the processed column as a result of the contact between the rollers of the rolling mill and the workpiece. They mainly result from the distribution of forces, material stresses and friction phenomena that accompany the rolling process. These defects have no major impact on the strength of the post, but on the visual effect of the finished product. The defects in question relate only to the external surface. In order to improve the visual quality of the surface and prepare it for the painting operation, the surface is subjected to a grinding operation. Grinding can be carried out using various abrasive tools.

The discussed methods in this study concern the use of bulk tools and are implemented on special machine tools. The conclusions presented in the paper refer to the advantages and disadvantages associated with the grinding methods discussed.

Grinding columns with lattle blades

One of the well-known methods of abrasive machining is the abrasive tools in the form of flap discs. The process of grinding with abrasive web discs is a type of surface rim whose task is to give the machined surface a given roughness by machining, without any significant change in shape. Blade discs, which are used for grinding, are characterized by very high flexibility, which is why they have found application in grinding objects with simple and very complex shapes. They are used for machining elements made of aluminum, stainless steels, acid-resistant steels, brass, constructional steel, or more and more often in the processing of plastics.

The blades are intended for both face and circumferential grinding. Under the influence of centrifugal force, the blade leaves are in contact and affect the machined surface by changing the rotational speed ns and pressing force F (Fig. 1).

Blade discs belong to the group of coated abrasive products due to their structure (Fig. 2). The nonwoven substrate is made of non-woven synthetic fibers, with a predominance of polyamides, which are characterized by high resilience of deformations. Thanks to the use of high-strength resins (binders), small abrasive particles are attached to the fiber. The most commonly used are silicon carbide or silicon carbides. The distribution of abrasive

Fig. 1 Grinding with a flap disc: a) peripheral, b) front [8]
Rys. 1. Szlifowanie tarczą listkową: a) obwodowe, b) czołowe [8]

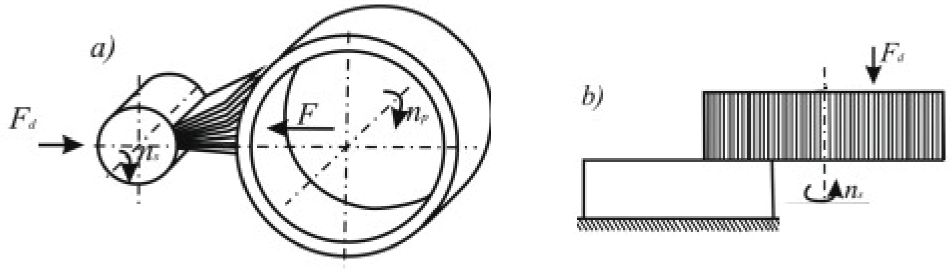
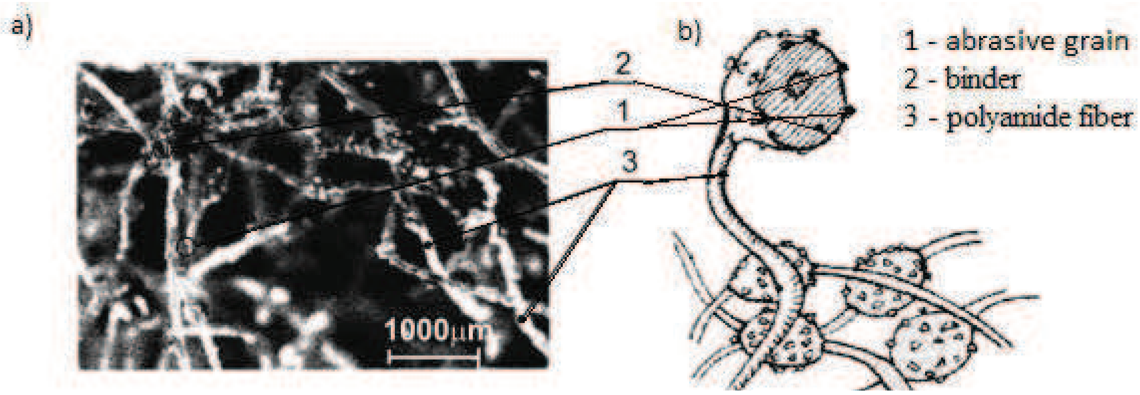


Fig. 2. Structure of the abrasive non-woven fabric: a) microscope photo, magnification: x15; b) abrasive non-woven model [8]
Rys. 2. Struktura włókniny ściernej: a) zdjęcie mikroskopowe, pow. 15×; b) model włókniny ściernej [8]



particles is chaotic, but occurs on the entire surface, thus creating a relatively homogeneous structure. Uneven distribution is very important during grinding operations. The blade disc must have a suitably shaped body.

Non-woven abrasive has many advantages. Through uniform distribution of the grains, a homogeneous structure is created that allows to maintain constant invariable working conditions. The fiber bonds provide heat dissipation - ventilation, which is very good conditions in the cutting zone, preventing overheating of the surface layer. In addition, fine dirt is picked up from the treated surface, which causes the process to be carried out by a "clean" non-woven fabric. Thanks to the very good flexibility, the blade leaves adapt to the shape of the workpiece. Blade discs are safe to use and are suitable for automated processes, therefore they are increasingly used as part of abrasive devices for special applications.

The characteristics of the grinding disc process are based on intermittent cutting and constant renewal of the grains in contact with the workpiece, in relation to their wear, dulling or breaking out of the abrasive fleece. The main feature of the abrasive web disks is to obtain a homogeneous geometrical structure on the surface of the workpiece. At the same time removing all kinds of burrs, sharp edges do not cause deterioration of shape and dimensions.

Blade discs were also used in the process of grinding aluminum lighting poles to remove surface defects after the rolling process. The machining is carried out in a special position. This device sets the workpiece which is the lighting pole in a rotary motion. In parallel to the axis of the workpiece, a working part is attached, which includes a drive unit with a head for mounting disc blades. An overview photo of the position is shown in Fig. 3.

The disadvantage of this solution is relatively expensive purchase of leaf blades and their short exploitation. In addition, the aluminum grinding process produces aluminum dust in large quantities, which is very dangerous. Aluminum dust may burn out or ignite, causing a fire hazard. Another disadvantage is the employee aspect related to the exposure of employees to harmful chemical and physical agents at the workplace.

The process of grinding poles with the help of leaf discs on the presented stand is a non-economical

Fig. 3. Stand for cleaning lighting columns with disc blades
Rys. 3. Stanowisko do czyszczenia słupów oświetleniowych tarczami listkowymi

process, inefficient and creating a threat of aluminum dust explosion. For this reason, the idea of creating a new workstation was born, which eliminates the above-mentioned disadvantages and increases productivity and comfort of work. This applies to machining with abrasive belts.

Grinding columns with endless tapes

Abrasive belts belong to the group of coated abrasive tools. They have the largest production applications in the industry due to the way they are made. They are made to the desired width and length by punching on special machines from rolled abrasive products. The pre-cut ends are joined and glued according to a specially developed technology. One can distinguish tapes with one-layer, multilayer and spatial embankments. They are mainly made of electrocorund and silicon carbides. Due to the method of application, tapes with abrasive applied by gravitation or in the electrostatic field can be distinguished. According to the purpose of the tape, it is divided into: full (closed) embankment 100% surface coverage, semi-open embankment 70-90% coverage and sparse (open) embankment with a coverage of 50-70% of the surface grains. Another division of the tapes that can be distinguished in terms of the connection of the ends of the tape is an overlapping (impact) connection or a contact joint (without impact). The strip joint is a critical zone, because the connection results in the interruption of the uniformity of the abrasive applied. By standards and standards, the tensile strength at the joint should not be less than the strength of a solid abrasive belt. In fact, the strength of the joint (suture) determines the strength of the entire belt. In practice, it applies equal types of connectors (Fig. 4).

The most commonly used are tapes with standard overlap joints. With the width of the strip smaller or equal to the width of the abrasive roll, endless bands are sewn with the seam at an angle (45-65°). In the case of a width greater than the width of the roll, the seam is used at an angle (5-65o). The standards also specify the thickness and width of the seam. The width cannot exceed 15 mm. For the thickness for P8-P120 granulation

Fig. 4. Types of connections of endless abrasive tapes [4]
Rys. 4. Rodzaje połączeń taśm ściernych bezkońcowych [4

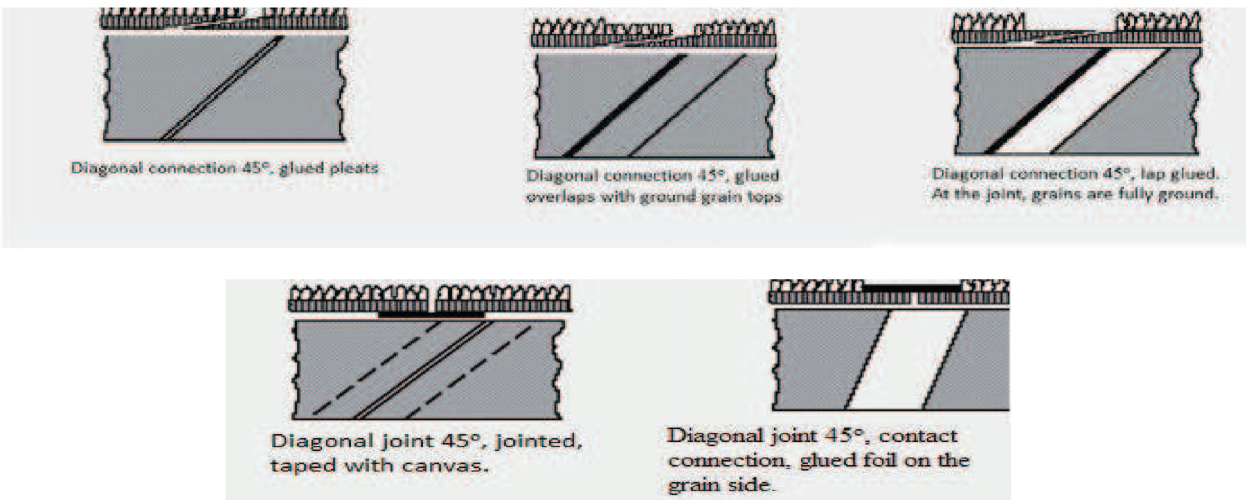
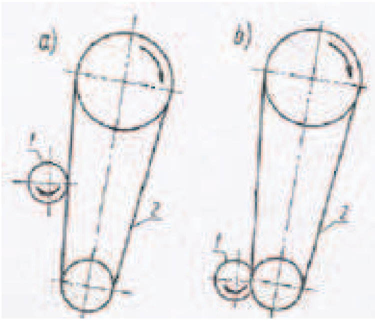


Fig. 5. Grinding with an endless belt a) free, b) support [9]
Rys. 5 Szlifowanie taśmą bezkońcową a) swobodne, b) podporowe [9]



should be less than 0,05-0,1 mm. For the granulation> P150 allows a seam thickness greater by 0.1mm than the thickness of the tape. All overlapping tapes must work in a specific direction in accordance with the mark on the ground (directional arrow). In practice, in the case of manual processing, tapes not exceeding 80 mm wide are used, while for mechanized machining, this width may in extreme cases amount to as much as 1500 mm. The width of the tapes and their length are selected depending on the shape of the workpiece, the possibilities of the machine tool and the method of tightening the belt.

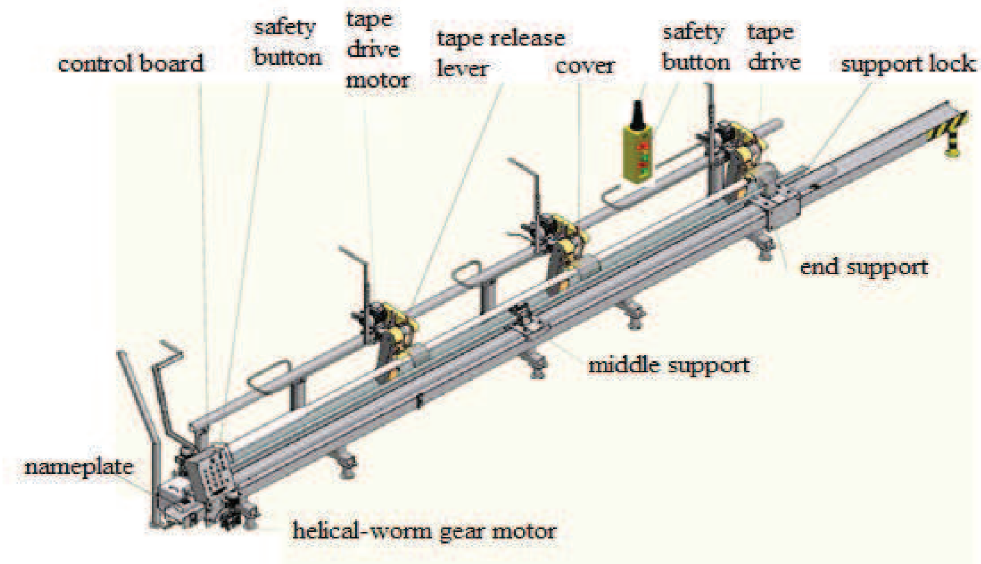
In order to make optimum use of the abrasive endless band, it is necessary to pay attention to the right type of abrasive grain, as well as the binder and substrate. Endless belts are widely used in the industry for grinding and polishing surfaces of workpieces made of metals, wood, glass, rubber, plastics and even concrete. They are also often used to clean surfaces from rust, varnish, etc.

Characteristics of the grinding process with abrasive belt always rests on the driving roller, which often also serves as a supporting element and on a loose roller. Loose roller is used to guide and tension the tape. If the machining is carried out on a part of the tape pressed by the disc (Fig. 5b), then the machining parameters are similar to the grinding wheels. Often, treatment is also applied to parts of the free tape (Fig. 5a).

One of the main parameters of the treatment is the determination of appropriate support and pressure elements, because their application, appropriate shape and size have a significant impact on the efficiency of the tool (endless belt), as well as on the efficiency of the entire grinding process. The pressure element and the processing site are of great importance in the grinding process. Their significance differs depending on the kinematic schemes of machine tools. If you do not use pressure elements when processing with an endless band, and you get the right tension of the tape, we get very large possibilities of surface treatment with a complicated shape.

The use of endless belts in the process of grinding light poles solves problems related to the economy and process safety, which have been described earlier. The implementation of the process requires a special machine tool, the construction scheme of which is shown in Fig. 6. The machine has a supporting frame on which three independent cleaning heads are mounted. Each head has interchangeable abrasive tapes that are water-cooled. Thanks to such application, the problem of pollination during machining was solved. The workpiece, which is a cone shaped lighting tower, is mounted on the machine supports. One of the supports is a driving support that puts the pole in a rotating motion. In parallel to the axis of the workpiece, three heads are positioned at the correct

Fig. 6. Diagram of a column grinding machine using endless belts.
Rys. 6 Schemat maszyny do szlifowania słupów za pomocą taśm bezkońcowych



distance and equipped with endless belts that perform grinding. Due to the appropriate selection of rotational speed, feed and the appropriate pressure, grinding/polishing of cylindrical or conical surfaces is performed.

Thanks to the use of endless abrasive belts for grinding elements with variable geometry, which is the lighting column, the efficiency of machining is increased by better matching (alignment) of belts to the workpiece. The use of three independent heads significantly improves the efficiency of the process. However, due to the water cooling solution, the pollination to the minimum is limited, which improves the working conditions for operators. An important aspect is also the purchase of consumables such as endless belts, which are 3x cheaper compared to flap discs and the service life is higher.

Conclusions

Methods of abrasive processing with bulk materials are still at the stage of intensive development. The pressure of manufacturers of abrasives exerts an influence on the improvement of products and their parameters. New materials, machine tool and component construction, and abrasive tool constructions create new possibilities for manufacturing processes. Continuous improvement and introduction of new products has contributed to the increasingly popular use of grinding using an endless belt. Grinding with this method for a long time was mainly used for finishing of elements made of wood and wood-like materials. The next phase of development of this technology was its application to treatments such as blunt sharp edges, grinding of risers and various types of flash. Currently, the most popular use of endless belts is finishing / polishing of steel, aluminum, stainless steel and acid resistant steel.

As a result of the combination of both grinding methods, it can be concluded that the use of endless abrasives for grinding light poles is a better technology solution. The superiority of this method is to better match and adhere belts to workpieces that have the shape of a cone. The use of tapes also has a positive effect on the economic aspect associated with the purchase and the lifetime of the tools.

Presented methods of grinding conical surfaces served the idea of creating a new station - a machine for grinding conical surfaces of aluminum lighting poles with embossed tools. This project will meet the requirements regarding both the correctness of the implementation of the treatment process and the principles of work safety. The performed position will allow to conduct research on the impact of selected abrasive machining parameters on the quality and efficiency of machining. Obtained results of tests in the process of grinding conical surfaces with bulk materials at the created stand will serve as a verification of the adopted assumptions and results obtained on the theoretical path.

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ANALYSIS OF SIZE AND SHAPE OF ABRASIVE MICROGRAINS IN LAPPING OF ASSEMBLY JOINTS

Analiza rozmiarów i kształtu mikroziarn ściernych w docieraniu połączeń montażowych

Анализ размеров и формы абразивных микро зерн в притирке сборочных соединений

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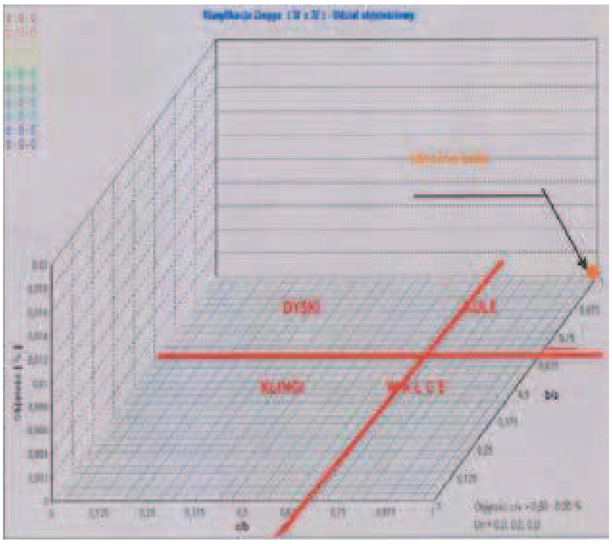
A b s t r a c t: In the paper, automated analysis of size and shape of abrasive micrograins was presented. In the tests of the micrograins of boron carbide, silicon carbide and electrocorundium, the stereoscopic microscopy and the specialized software MultiScan v.6.08 were applied.
K e y w o r d s : abrasive micrograins, size, shape, measurements
S t r e s z c z e n i e: W pracy przedstawiono skomputeryzowaną analizę wielkości i ksztaltu mikroziaren ściernych. W badaniach mikroziaren weglika boru, weglika krzemu i elektrokorundu zastosowano mikroskopię optyczną oraz specjalistyczne oprogramowanie MultiScan v. 6.08.
S ł o w a k l u c z o w e : mikroziarna ścierne, wielkość, kształt, pomiary

Introduction

One of the methods for machining, employed in assembly technologies, is lapping of the surface of componential elements with a loose abrasive. The aim may concern obtaining a required dimension of technological compensator, or individual fitting of immobile or mobile joints. The run and the results of lapping are affected by many kinetic, technological and material factors. The quality of lapping factor is one of the major parameters; it concerns mainly the stereometry, applied in the lapping suspension or paste of micrograins [2]. At present, there are many types of abrasive pastes, offered by trade, both traditional as well as diamond ones which may be utilized in shaping the assembly joints [1]. Due to the chemical components, the time of utilization of abrasive pastes is limited. Therefore, in practice and especially in the case when there is a need of the small portions of the pastes, being often differentiated in respect of the type of abrasive and size of micrograins, the specified batches of the pastes are prepared directly before their use in the lapping process. The mentioned situation may have also place in the case of assembling a prototype or during the experimental tests. Lapping may be performed irrespectively of the type of materials of the componential elements. Ensuring the specified requirements in respect of the state of the shaped joints requires control of the size of abrasive before the preparation of the paste.

Zingerra classification [6] is often used in analysis of the shape of the micrograins. It distinguishes four basic forms: discs (b/α >2/3), balls, blades (b/α <2/3 and c/b <2/3) and rollers (b/ α <2/3 and c/b >2/3) (Fig.1) where the dimensions of the grains, occurring in the space are: α – length; b – width; c – height, respectively (dimensions are correlated in the system of three main axes: long, medium and short). According to FEPA standard 42-D—1984 (Federation of the European producers of Abrasives) [17] it is also possible to use the mean size of the micrograin (Tab. 1).

Fig. 1. Zingga diagram [6]
Rys. 1. Diagram Zingga [6]



Tab. 1. Size of abrasive micrograins by FEPA [17]
Tab. 1. Wielkości mikroziaren ściernych wg FEPA [17]

Marking of abrasive micograins	Mean size [μm]
F230	56.0 – 50.0
F240	46.5 – 42.5
F280	38.5 – 35.0
F320	30.7 – 27.7
F360	24.3 – 21.3
F400	18.3 – 16.3
F500	13.8 – 11.8
F600	10.3 – 8.3
F800	7.5 – 5.5
F1000	5.3 – 3.7
F1200	3.5 – 2.5

During the lapping process, the individual abrasive micrograins change not only the shape but also the size. The mentioned transformations [10] describe their shape (approximation of the shape to ellipse) (Fig.2), distribution of the size (circle inscribed in a single grain) (Fig.3) and the so-called "sharpness" SV (on the basis of Richardson technique) (Fig.4). In case of approximation of the grain shape to ellipse, we may distinguish as follows: coefficient of proportion AS = a/b, coefficient of elongation EL = log2 (a/b) and coefficient of dispersion DP = log2 (πab).

In the lapping process, the change in distribution of the size of micrograins in the zone of treatment has place (Fig.5), so the working slot is decreased and changes the load of individual grain. In the case of periodical dosage (supplementation) of abrasive paste, the process of lapping may be intensified. A single dosage of lapping agent enables, however, obtaining of lower values of coarseness parameters of the shaped surfaces.

In practice, there are few methods for evaluation of the size and shape of micrograins applied, mainly the sedimentation, microscopic and laser methods [4, 5, 7, 8, 11, 15, 16]. Segregation according to the size may be performed via the stream of swirling or direction-changing air, separation as a result of washing out with water, by gravitational sedimentation or by centrifugal force. For analysis of the degree of wear of the grains, optical and scanning microscopy, roentgen and laser analysis may be utilized. In the case of the size of micrograins, optical-electronic microscopes (e.g. 2DiSA by Kamika) [14] or laser microscopes (e.g. Analysette 22 nano Tec by Fritsch company) are very useful. In the discussed below studies, the computerized stereoscopic microscopy was employed [9].

Fig. 2. Definition of the shape of abrasive micrograins [10]
Rys. 2. Określenie kształtu mikroziarna ściernego [10]

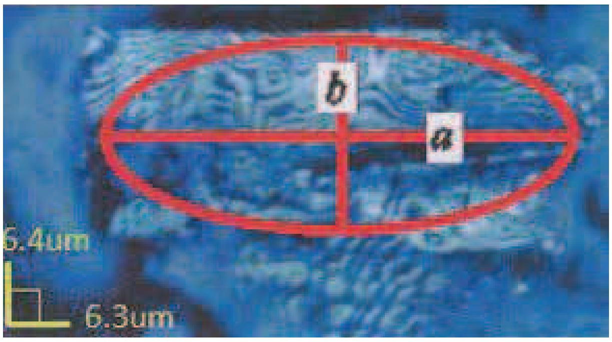


Fig. 3. Definition of the size of abrasive micrograins [10]
Rys.3. Określenia wielkości mikroziarna ściernego [10]

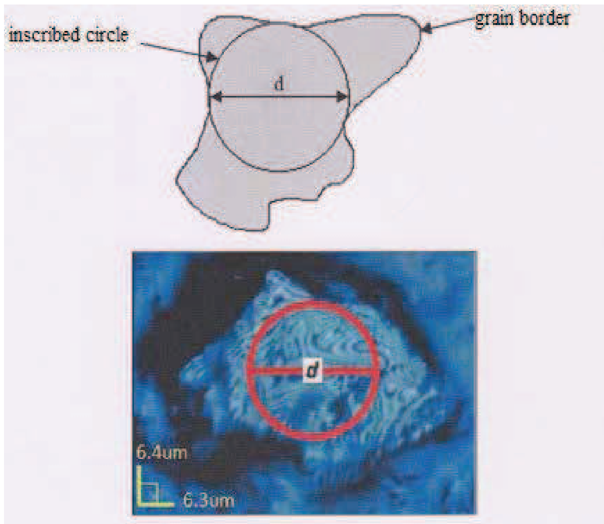
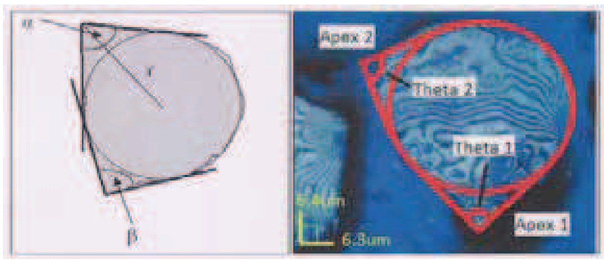


Fig. 4. "Sharpness" of abrasive micrograins (β>a, SV=cos β/2) [10]
Rys. 4. "Ostrość" mikroziarna ściernego (β > α, SV = cos β/2) [10]



Measurement test stand and methodology of the studies

For measurements of the size and shape of the abrasive micrograins, the setup equipped in stereoscopic microscope, CCD camera and software MultiScan n.6.08 (Fig. 6) was used. Before analysis of the micrograins, scattered on the white surface, it is necessary to perform a precise regulation of the exposition, depth of colour and contrast in the window of Camera - HB Series twain

Fig. 5. Probability distribution P(d) of abrasive micrograin size d at different lapping time (after t = 15 sec. - analysis 62 micrograins, after t = 90 sec. - 90 micrograins, after t = 180 sec. - 100 micrograins, after t = 250 sec. - 100 micrograins) [3]
Rys. 5. Rozkład prawdopodobieństwa P(d) wielkości mikroziarna ściernego d w czasie docierania (po t = 15 sekundach analizowano 62 mikroziarna, po t = 90 - 101 mikroziaren, po t = 180 - 100 mikroziaren, po t = 250 - 100 mikroziaren) [3]

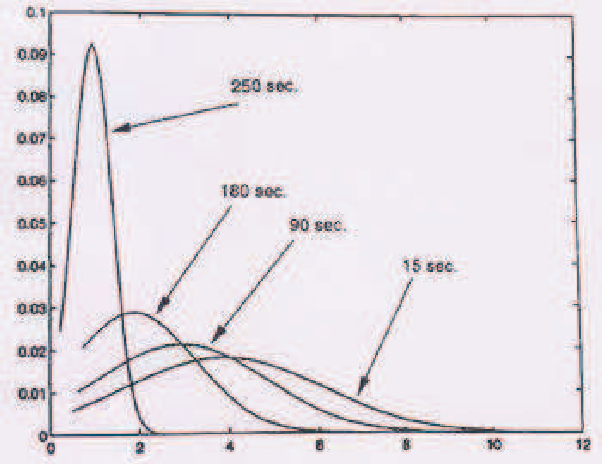
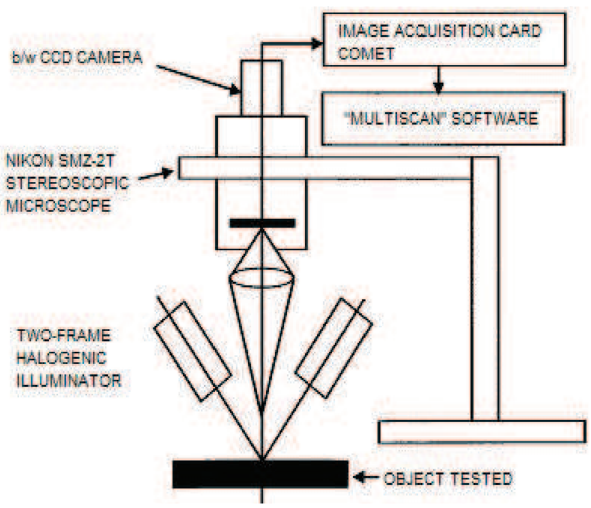
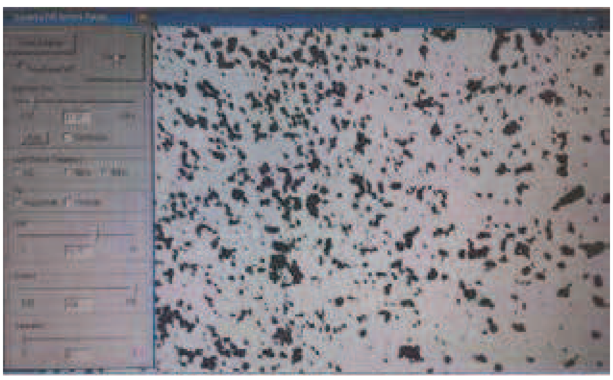


Fig. 6. Scheme of measurement stand and software used
Rys. 6. Schemat stanowiska pomiarowego i okno programu

a)

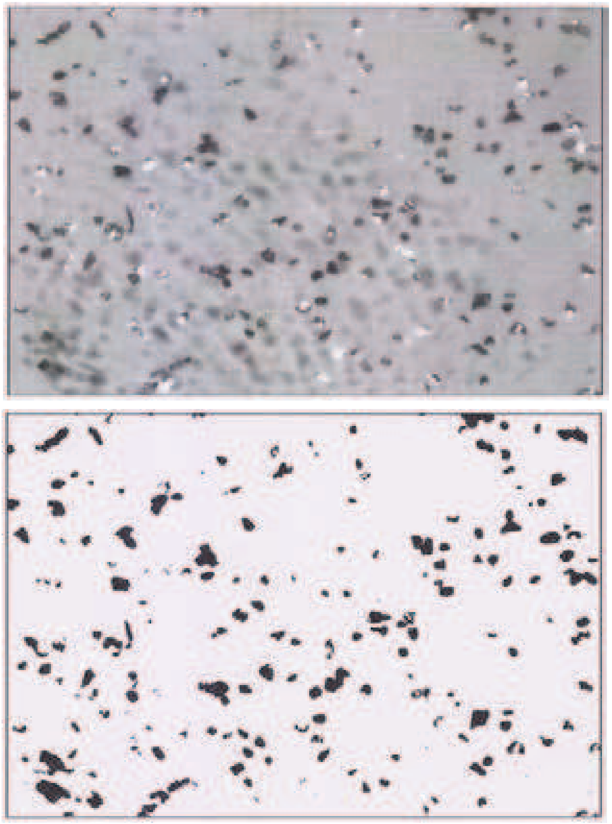


b)



and adapt the light to the conditions of the environment (existing in a room), fix the magnification of the image and regulate its sharpness [12]. The image of the analyzed batch of the abrasive micrograins is saved in a form of BMP file, with the application of binarizing filters which enable removal of the shade of background and a degree of grey colour of the particular grains (Fig. 7).

Fig. 7. View on abrasive micrograins (95A F 500): a) before filtration, b) after filtration
Rys. 7. Widok mikroziaren elektrokorundu (95A F500): a) przed filtracją, b) po filtracji

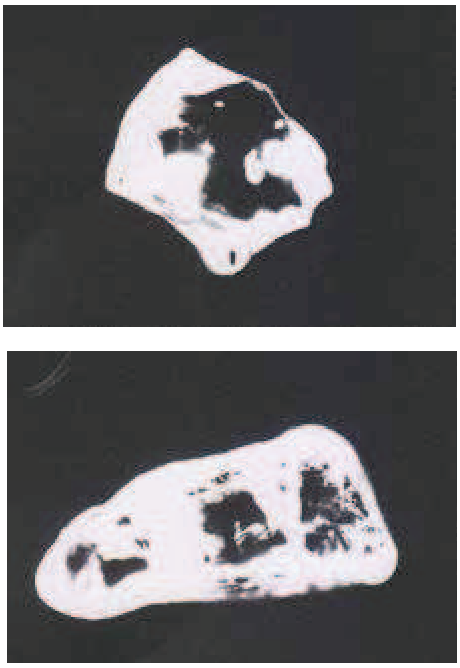


During the first filtration stage, the image is obtained in which the grains adopt black colour on a white background, however in the particular examined objects there also visible white fields being the residues of light reflexes coming from the primary microscopic image (Fig. 8). The removal of the mentioned reflexes occurs by the so-called "filling the openings", using negative and binarization. Calibration of stereoscopic microscope (pattern of 1-mm segment was divided into 100 parts) was carried out with the 6-fold magnification, identical as during the measurements of the particular grains.

Minimum size of the examined batches $n = z_a^2\sigma^2/e^2$ was determined for confidence interval 1-a =0.9 at multiple of standard error of mean for $z_a = 1.96$ and the assumed maximum error e = 0.1. Standard Deviation σ was determined in a preliminary test. The maximum

Fig. 8. Images of abrasive micrograins: a) before modification, b) after filtration
Rys. 8. Obrazy ziaren ściernych: a) przed modyfikacją, b) po filtrowaniu

a)



b)

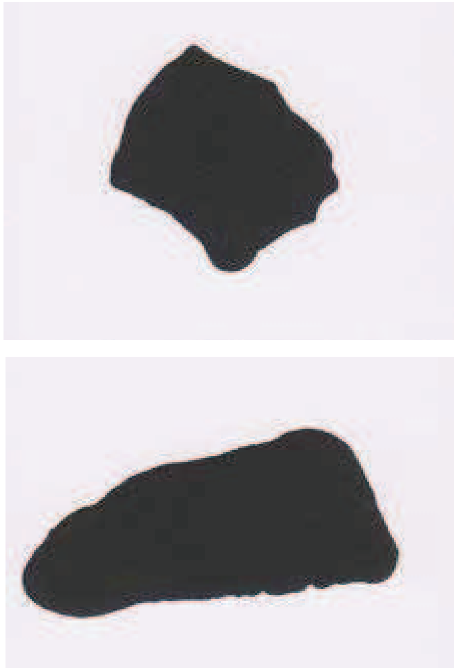
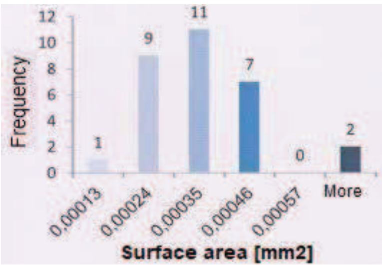
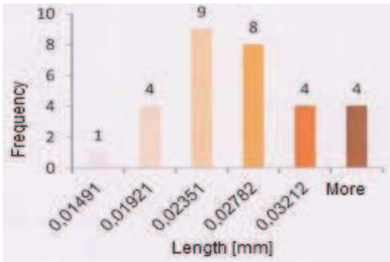


Fig. 9. Measurements of abrasive micrograins 95A F 500: a) distribution of area A, b) distribution of length l, c) distribution of width s
Rys. 9. Pomiary mikroziaren 95A F500: a) rozkład pola powierzchni A, b) rozkład długości l, c) rozkład szerokości s

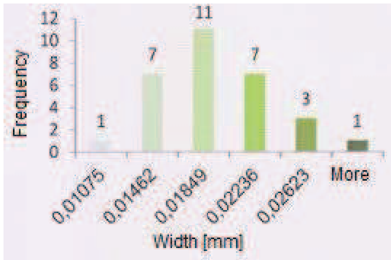
a)



b)



c)

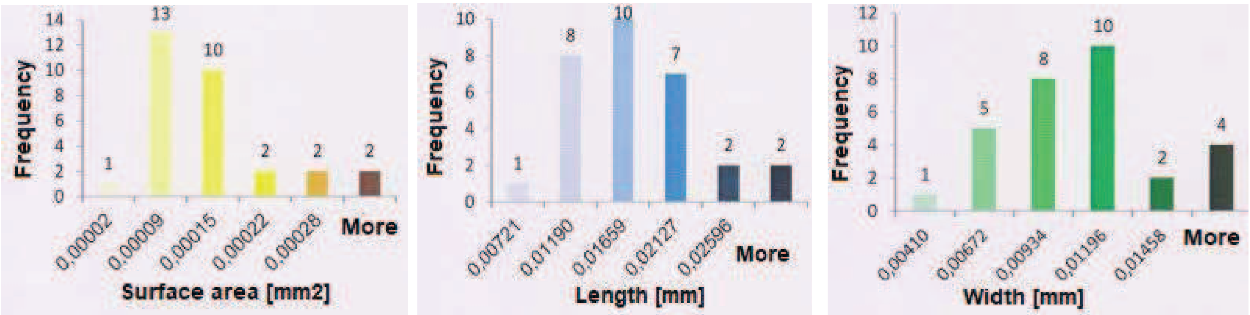


Tab. 2. Characteristics of distributions of abrasive micrograins 95A F 500
Tab. 2. Charakterystyki rozkładów mikroziaren 95A F500

	Surface area *A* [mm^2]	**Length *l* [mm]**	**Width *s* [mm]**
Arithmetical mean	0,00031	0,02448	0,01758
Standard error	0,00002	0,00100	0,00078
Median	0,00027	0,02374	0,01716
Range	0,00056	0,02038	0,01935
Standard Deviation	0,00013	0,00550	0,00427
Variance	0,00001	0,00003	0,00002
Kurtosis	2,38359	-0,42332	1,01901
Skewness	1,42563	0,49578	0,83003

Fig. 10. Measurements of abrasive micrograins BC F 600: a) distribution of area A, b) distribution of length l, c) distribution of width s
Rys. 10. Pomiary mikroziaren BC F600: a) rozkład pola powierzchni A, b) rozkład długości l, c) rozkład szerokości s

a) b) c)

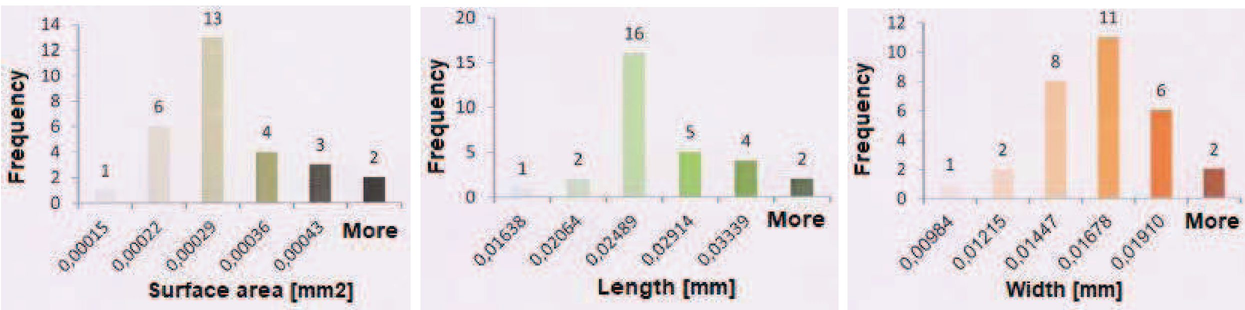


Tab.3. Characteristics of distributions of abrasive micrograins BC F 600
Tab. 3. Charakterystyki rozkładów mikroziaren BC F600

	Surface area *A* [mm^2]	Length *l* [mm]	Width *s* [mm]
Arithmetical mean	0,00012	0,01502	0,00965
Standard error	0,00001	0,00099	0,00065
Median	0,00010	0,01471	0,00950
Range	0,00032	0,02344	0,01309
Standard Deviation	0,00008	0,00542	0,00356
Variance	0,00001	0,00003	0,00001
Kurtosis	2,44899	1,71377	-0,14006
Skewness	1,57688	1,14321	0,47499

Fig. 11. Measurements of abrasive micrograins 98 C F 500: a) distribution of area A, b) distribution of length l, c) distribution of width s
Rys. 11. Pomiary mikroziaren 98C F500: a) rozkład pola powierzchni A, b) rozkład długości l, c) rozkład szerokości s

a) b) c)



dimensions of the images of abrasive micrograins in space of observations were determined, measuring their length l and width s and surface area A.

The results of the studies

The conducted experiments included tests of common electrocorundium 95 A (30 micrograins were measured) with a normative (specified in sedimentation analysis) dimensions F 500, black silicon carbide 98 C F 500 (30 micrograins) and boron carbide BC F 600 (21 micrograins). Fig.9-11 contain the obtained histograms of the micrograins' dimensions whereas Tables 2-4 give their basic characteristics.

The constructed distributive series of the examined geometrical parameters of the micrograins differ inconsiderably each other. For example, in the case of boron carbide micrograins, the distributions of the surface area A and of length l reveal a positive asymmetry (right

Tab. 4. Characteristics of distributions of abrasive micrograins 98 C F 500
Tab. 4. Charakterystyki rozkładów mikroziaren 98C F500

	Surface area *A* [mm^2]	Length *l* [mm]	Width *s* [mm]
Arithmetical mean	0,00029	0,03931	0,01553
Standard error	0,00002	0,00346	0,00047
Median	0,00027	0,03133	0,01537
Range	0,00037	0,06491	0,01157
Standard Deviation	0,00010	0,01897	0,00255
Variance	0,00001	0,00036	0,00001
Kurtosis	0,68596	-0,36061	0,18764
Skewness	0,97009	0,89248	0,12248

Tab. 5. Analysis of the shape of abrasive micrograins 95A F 500
Tab. 5. Analiza kształtu mikroziaren 95A F500

No.	Length *l* [mm]	Width *s* [mm]	Coefficient of proportion $AS = l/s$	Coefficient of elongation $EL = log_2(l/s)$	Coefficient of variation $DP = log_2(\pi ls)$
1	0,023	0,019	1,20	0,26	-9,45
2	0,019	0,012	1,58	0,66	-10,47
3	0,015	0,011	1,39	0,47	-10.96
4	0,029	0,024	1,20	0,26	-8,87
5	0,025	0,018	1,40	0,49	-9,44
6	0,017	0,014	1,17	0,22	-10,35
7	0,029	0,018	1,61	0,69	-9,20
8	0,032	0,023	1,38	0,47	-8,76
9	0,021	0,015	1,39	0,48	-9,98
10	0,036	0,022	1,64	0,71	-8,62
11	0,020	0,016	1,26	0,34	-9,95
12	0,019	0,018	1,05	0,07	-9,91
13	0,027	0,021	1,25	0,32	-9,14
14	0,024	0,019	1,25	0,33	-9,48
15	0,023	0,014	1,61	0,68	-9,95
16	0,020	0,012	1,72	0,78	-10,39
17	0,035	0,030	1,17	0,23	-8,23
18	0,018	0,013	1,38	0,46	-10,34
19	0,026	0,021	1,22	0,29	-9,18
20	0,024	0,020	1,17	0,22	-9,35
21	0,021	0,019	1,09	0,12	-9,63
22	0,025	0,014	1,82	0,87	-9,84
23	0,024	0,016	1,55	0,63	-9,69
24	0,026	0,015	1,72	0,78	-9,65
25	0,032	0,023	1,41	0,49	-8,76
26	0,022	0,014	1,53	0,61	-9,95
27	0,029	0,015	1,98	0,99	-9,51
28	0,020	0,017	1,16	0,21	-9,83
29	0,032	0,017	1,90	0,92	-9,19
30	0,020	0,015	1,33	0,41	-10,10
Mean			**1,42**	**0,48**	**-9,61**

side) while in the case of width s of the microscopic images of the micrograins, there is a lack of such asymmetry what means greater dispersion of the results. In the measurements of silicon carbide micrograins, the obtained distributions are approximate to a normal one; the results are focused around the mean value and the coefficients of skewness are near to one – what is an evidence of a lack of asymmetry of distributions. When comparing the parameters of the shape of the micrograins of electrocorundium 95 A and of silicon carbide 98 C, with the same normative number F 500 (Tab. 5 and 6), it is easy to notice that the mean coefficient of proportion AS and the coefficient of elongation EL is higher for the grains of silicon carbide. It means that the mentioned grains have more elongated shape. The negative values of the variability coefficient DP indicate a big dispersion of the results of the measurements of the grains, both of the length l and of the width s. It may be, however, generally stated that the examined micrograins of electrocorundium and silicon carbide do not reveal any significant differences in respect of their shape. Due to the small differences in the examined geometrical parameters and time consumption of the evaluation in the conducted analysis, it was adopted that the length of the image l ≈a and the measured width s ≈ b (Fig. 2).

Summary

When conducting the microscopic measurements of the dimensions of abrasive micrograins, the attention should be paid to the following facts:

- The abrasive micrograins cannot be damp or glued together,

Tab. 6. Analysis of the shape of abrasive micrograins 98 C F500
Tab. 6. Analiza kształtu mikroziaren 98C F500

No.	Length *l* [mm]	Width *s* [mm]	Coefficient of proportion *AS= l/s*	Coefficient of elongation *EL= $log_2(l/s)$*	Coefficient of variation *DP = $log_2(\pi ls)$*
1	0,016	0,012	1,33	0,42	-10,70
2	0,017	0.011	1,55	0,63	-10,73
3	0,016	0,013	1,23	0,30	-10,58
4	0,021	0,010	2,10	1,07	-10,57
5	0,019	0,014	1,36	0,44	-10,23
6	0,023	0,014	1,64	0,72	-9,95
7	0,021	0,014	1,50	0,58	-10,08
8	0,026	0,012	2,17	1,12	-10,00
9	0,022	0,015	1,47	0,55	-9,91
10	0,023	0,015	1,53	0,62	-9,85
11	0,024	0,015	1,60	0,68	-9,79
12	0,021	0,013	1,62	0,69	-10,19
13	0,026	0,013	2,00	1,00	-9,88
14	0,021	0,016	1,31	0,39	-9,89
15	0,024	0,014	1,71	0,78	-9,89
16	0,021	0,017	1,24	0,30	-9,80
17	0,023	0,016	1,44	0,52	-9,76
18	0,022	0,016	1,38	0,46	-9,82
19	0,023	0,016	1,44	0,52	-9,76
20	0,022	0,019	1,16	0,21	-9,57
21	0,031	0,016	1,94	0,95	-9,33
22	0,023	0,019	1,21	0,28	-9,51
23	0,031	0,014	2,21	1,15	-9,52
24	0,026	0,016	1,63	0,70	-9,58
25	0,027	0,020	1,35	0,43	-9,20
26	0,031	0,016	1,94	0,95	-9,33
27	0,028	0,019	1,47	0,56	-9,23
28	0,030	0,021	1,43	0,51	-8,98
29	0,035	0,018	1,94	0,96	-8,98
30	0,038	0,017	2,24	1,16	-8,95
Mean			**1,60**	**0,66**	**-9,78**

- The external light cannot cause the occurrence of numerous shadows of the examined objects,
- In the case of occurrence of the light reflexes of the micrograins which have not been removed in the stage of image filtration, they should be omitted in the analysis,
- The distribution of the micrograins on the white surface should be sufficiently dispersed,
- Light scanning microscopy should not be used to very fine micrograins (with normative number F 1200 and smaller).

In spite of the above mentioned limitation, utilization of computerized microscopic methods in the evaluation of the size and shape of the abrasive micrograins in the procedures of assembly lapping may be technologically effective and economically justified.

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ASSEMBLY AND SETUP OF UNTYPICAL TOOLS IN CNC LATHE

Montaż i bazowanie nietypowych narzędzi w tokarce CNC

Сборка и базировка нестандартных инструментов в токарном станке

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Abstract: In the paper, the possibilities of measuring and setup of cutting tools, using electronic microscope, were presented. The problem refers to applying the tools mounted in unconventional places of the machine tool workspace. In this case, standard measuring systems of cutting machines do not allow a correct measuring and setup of the tools. The presented method is characterized by a flexibility of placing of the mounted tool, high resolution and repeatability. Additionally, the discussed method allows checking the geometry and the state of wear of the cutting edge of the tool, e.g. the chipping of the blades.
Keywords: cutting tools, tool setting, tool assembly, chipping control
Streszczenie: W artykule zaprezentowano możliwości pomiaru i ustawienia narzędzi skrawających za pomocą mikroskopu elektronicznego. Problem dotyczy narzędzi montowanych w niekonwencjonalnych miejscach przestrzeni roboczej obrabiarki. W takim przypadku standardowe systemy pomiarowe obrabiarek nie pozwalają na prawidłowe mierzenie i bazowanie narzędzi. Przedstawiona metoda cechuje się elastycznością co do miejsca aplikacji, dużą rozdzielczością i powtarzalnością. Ponadto omówiony sposób pozwala na kontrolę geometrii i stanu zużycia krawędzi skrawającej np. pod kątem wykruszenia ostrzy.
Słowa kluczowe: narzędzia skrawające, ustawienia narzędzi, montaż narzędzi, kontrola wyszczerbień

Introduction

In the computerized numerical control (CNC) machines, the rate and precision of preparing the tools and the elements to the machining process is very important due to the expected effectiveness. Their accurate measuring and position in the workspace is indispensable for a correct work. It is a preparatory process which consists of a series of operations, performed by the operator. Manual measurements, setup and introduction of the data concerning the offsets are time-consuming operations, endangered by errors. At present, there are universally employed measuring systems together with the dedicated software, integrated with the lathe control system. To read the position of the tools, they utilize measuring systems of the lathe axis. The probes for setup of the tools are easy in installation in the machining centres and allow making the operations automated. They ensure considerable saving of time, a precise measurement, automatic correction of tool offsets and eliminate the errors of manual setup. The modern solutions allow obtaining information on a radial and linear profile of the tool and state of cutting edge. They enable also a current monitoring of the tool wear. The measurement after a specified time period and automatic introduction of the current correction gives a guarantee of stability of the machining process [2, 3, 5].

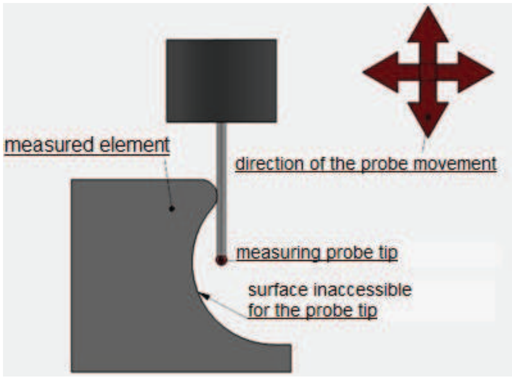
Methodology

In the machine industry, the contact and non-contact measuring systems are employed. In the first case (Fig.1), a physical touch of the tested object with the tool probe is necessary. The principle of its functioning consists in deviating of a contact part from neutral position due to the contact with the examined tool. Then, information from the probe is transmitted to the measuring device by a wire or in a wireless way, e.g. by radio or infrared light. Such method of performing the measurements has many advantages. It is characterized by resistance to the contamination in the workplace, simplicity and small dimensions of the subunits. The drawbacks of the method include the fact that the measurements implemented by the discussed method may deform the low-rigidity elements. The successive limitation concerns the size of the touch probe tip which cannot always be located in small workplaces [2 -5, 7].

The measurement of elements with complicated shapes becomes troublesome or even impossible when there is no possibility of the “approach” due to the kinematics of the machine. The problem is presented in a form of scheme in Fig. 2.

Fig. 1. System of touch measuring probes [11]
Rys. 1. System dotykowych sond pomiarowych [11]

Fig. 2. Difficulties occurring during the measurement, using a probe
Rys. 2. Utrudnienia występujcie podczas pomiaru sondą pomiarową



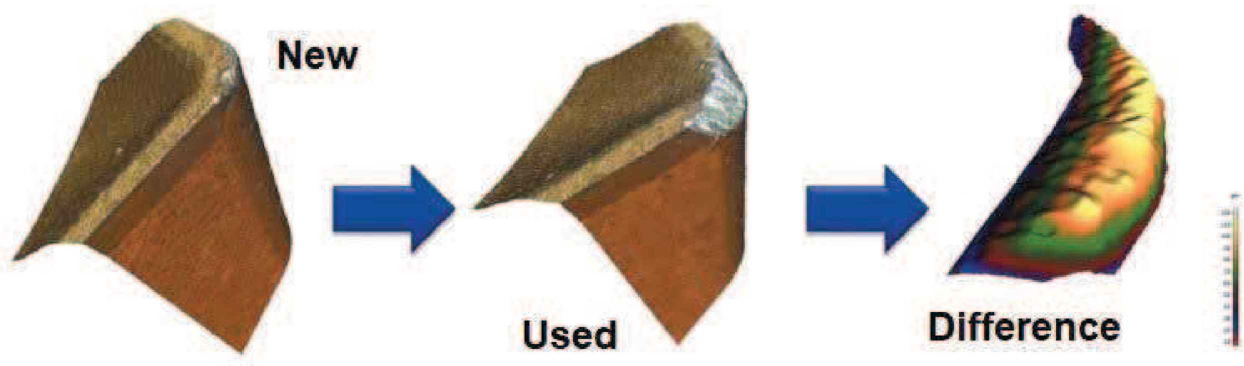
Contactless measuring systems are more and more frequently used in CNC lathes. Their growing popularity results from their significant advantages e.g. they offer the possibility of measuring the element sensitive to the deformation caused by touch; they also allow detecting the cutting edges. They may be used even at a high rotary speed of the spindle.

The systems, operating on the principle of measurement of reflection of laser light from the tool surface are characterized by a high level of resolution, perfect linearity and the possibility to measure the objects with a coarse surface. During the contactless measurement, the tool rolls over the laser radius and cuts it, releasing the measurement. Optical probe utilizes the phenomenon of shadowing the light ray or change in the level of lighting. The application of the discussed probes gives the possibility of measuring the tool before the treatment (in order to introduce the correction to the machining program) as well as during the process in order to compensate the worn edge. It is also possible to perform the measurements from a big distance from the object. We may distinguish the measurements where the transmitter and the receiver are situated in one element, or in the separate elements. The laser beam measures the length, diameter or contour of the tool. Difficult conditions of workspace are the limitation of the method; hence, the systems of treatment with a compressed air, removing chips and refrigerant are employed [1, 6, 8].

Fig. 3. System of contactless measurement of the tool, using laser beam [9].
Rys. 3. Układ bezdotykowego pomiaru narzędzia za pomocą wiązki lasera [9]

Apart from the measuring systems, constituting the integral part of the equipment of industrial lathes, a series of other solutions are successfully used. We should indicate here the coordinating machines, optical scanners, CT scans and many other solutions. In the context of the discussed problem, all of them have one common property, i.e. independent constructions which are not usually installed inside the machines. Due to their destination, they will be unsuitable for the precise setup of the tools in the lath. Despite it, we should pay attention to the optical micrometers. Similarly as laser systems, they allow the non-contact measuring of geometric size or coarseness, utilizing various measurement principles. The additional advantages of the discussed equipment include a high efficiency and a high precision. The measurements of the properties, as implemented by surface geometry technology create the new research possibilities and enable a new look at the problems of the cutting edge characterization. Wear of the tools and their state after a specified period of work are typical and universal problems during the machining process. The control of chipping and micro-cracks is significant. When using a microscope, we are able to scan a tool before

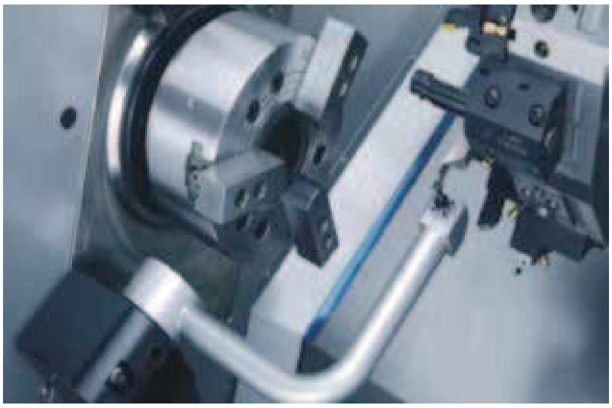
Fig. 4. Comparison of a fragment of a new tool and a worn tool [1]
Rys. 4. Porównanie fragmentu narzędzia nowego i zużytego [1]



treatment and after its completion (Fig. 4). It gives the possibility of reconstructing its full three- dimensional geometry. The obtained result allows conducting the accurate analysis of the edge quality. Owing to the application of the appropriate software, it is possible to overlap the obtained images each other, or to compare with CAD model and develop a map of deviations. The models may be analysed irrespectively of the type of the edge or a type of material [1].

Standard measuring systems in a form of probes are installed in the specified places of workspace of the lathes. After calibration of the system, the basic elements are not rearranged. In consequence, it works according to one scheme. It is a certain limitation. The lathe, on which the studies were carried out, may be the example. It is equipped in one probe for measurement of the tools, as it is given in Fig. 5.

Fig. 5. Measuring probe of the lathe [10]
Rys. 5. Sonda pomiarowa tokarki [10]



In the case of unconventional solutions, such accessories of the lathe do not have the possibility of determining the position and geometry of the tools which will not be installed in the turret lathe head. If we want to outline the essence of the problem more precisely, we should refer to a wider range of the studies. Their aim is to develop the technology, giving the possibility of grinding the screw surfaces in the universal CNC lathe. To this end, a special device was constructed (Fig. 6 and 7). It is assembled in the mentioned tool head. It moves as any tool, in accordance with the kinematics of the machine, using its drives and numerical control.

Fig. 6. Grinding in the lathe
Rys. 6. Szlifowanie na tokarce

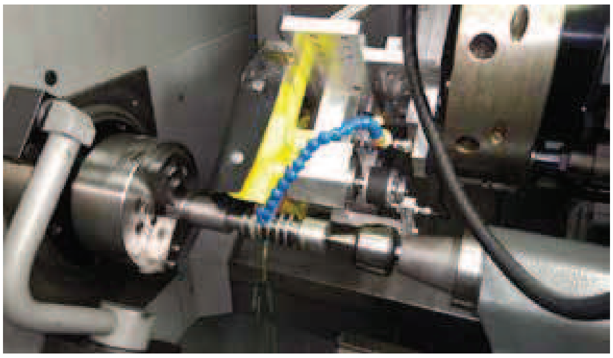
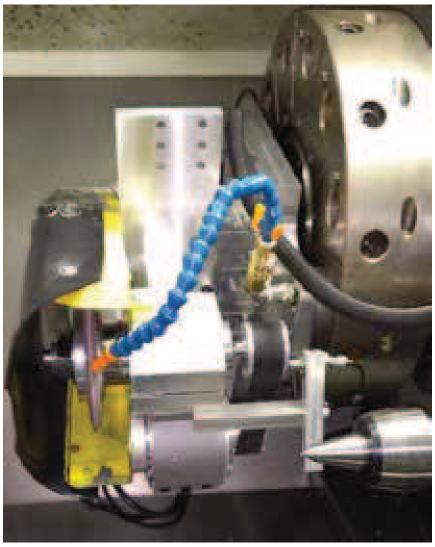


Fig. 7. Grinding tool
Rys. 7. Przyrząd szlifierski



In this case, we operate the grinding wheel, which is set up under the selected angle in relation to the axis of the treated object and it has its own drive. The presented solution is the first part of the research stand. The correct work of the grinding wheel requires appropriate preparation of its grinding surface. The mentioned process, called a dressing process, requires diamond dressers to be used. Due to the fact that the tool head is already occupied and besides it, the whole tool is moved, the dressers had to be installed in another, immobile place. The problem was solved via construction of additional special tool, constituting the second part of the stand. It is mounted on the tailstock grinder guides and immobilized in the selected position. The catching element allows mounting of three dressers. It gives the opportunity of grinding wheel treatment from each side in one mounting. The unit is illustrated in Fig. 8.

The correct setup and measurement of the tools and then, transmission of these data to the control system of the machine is the indispensable for effective and correct performance of NC program. The application of measuring probe is the most convenient method; however, when undertaking the attempt to perform the mentioned operations, there were many problems encountered.

The first one includes a lack of the possibility of “driving up” the mobile measurement probe to any place of workspace as it happens in milling machines (Fig.1). In the lathes, the treated object is always found in the axis of the spindle, and only its size is a variable. Due to this fact, the application of such probe is not justified.

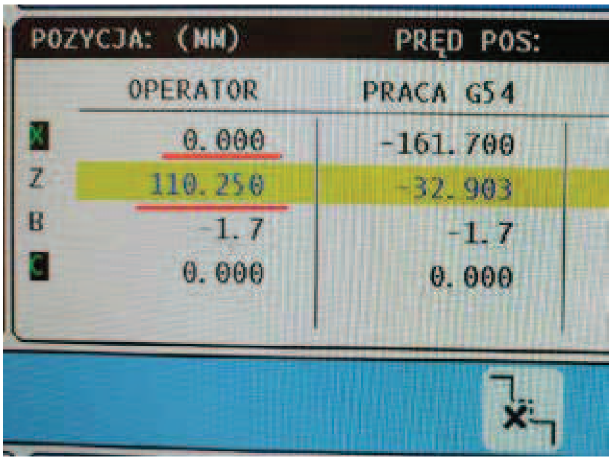
The second problem includes angular mounting of certain dressers. Even if it had been possible to use the mentioned earlier probe, there would be the problem of measuring the surface that is inaccessible for the contact part, as it was shown in Fig. 2.

The third limitation concerns the position of the dressers. The frames and sockets in the turret lathe head ensure standard distribution of the tools. It is necessary to perform only easy measurement of geometry and position of the edges. The dressers are found in a completely different place. Additionally, their manual removal from the holder “intuitionally” does not give the possibility of a precise setting up on the same height in relation to X axis.

The radius of the dresser is the fourth problem. Standard probe of the lathe allows measuring the tool from few sides. When knowing the position and radius of the grinding disc edge, the programmed calculation of the compensation of its contact point with the material for the arc passage. Due to very small dimensions of the dresser diamond, the measurement with the mobile head “from milling machine” would not give a reliable result as

Fig. 8. Microscope scanning
Rys. 8. Skanowanie mikroskopem

Fig. 9. The result of measurement of distance between the dressers in Z axis
Rys. 9. Wynik pomiaru odległości między obciągaczami w osi Z



it is not known what part of the probe tip will touch the diamond.

Due to the earlier mentioned limitations, the solution of the problem owing to the application of electronic microscope was presented. The method of its mounting was illustrated in Fig. 8. We should pay attention to the fact that small dimensions of the instrument give a big flexibility in respect of the application of different variants of assembling. In the discussed case, the standard tool frame and ER collet were employed and the appropriate bracket and the handle for microscope were placed inside. The whole set was mounted in one of the sockets of turret lathe head.

Fig. 10. The left dresser
Rys. 10. Lewy obciągacz

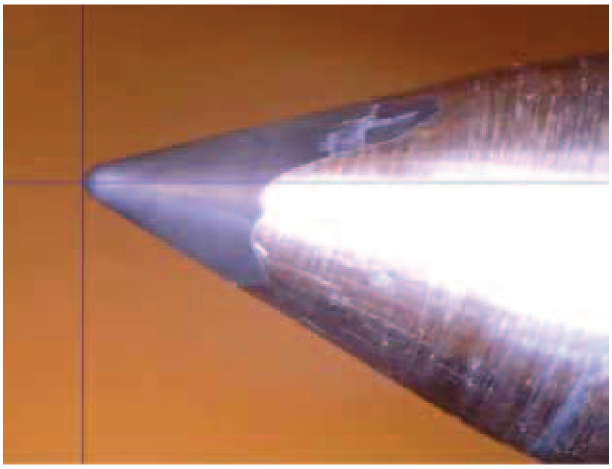
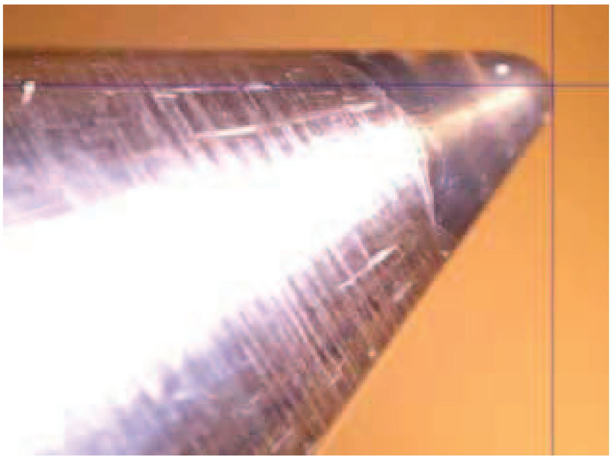


Fig. 11. The right dresser
Rys. 11. Prawy obciągacz



The measuring process is carried out during the preparatory work, before the assembly of target grinding tool. The microscope has USG interface to be connected with computer. The discussed procedure requires preliminary setup of the first dresser. To this end, it is necessary to fix the microscope via approaching of the head. After regulation of sharpness on the screen of the computer, a distinct image will be obtained. The software of the producer enables display of auxiliary lines. The point of their crossing should be found at the end of the dresser (Fig. 10). Then, the operator resets the position of X and Z axes in the lathe control system. It is possible to compare the obtained position and any earlier setup. Then, the microscope should be moved in the vicinity of the second dresser. In relation to X axis, the microscope must return precisely to the same position (Fig. 9, section OPERATOR, position X 0.000) and only Z axis is operated. When the dresser is visible on the screen, its diamond must be set up at the point of crossing of the same auxiliary lines, displayed in the computer program. To this end, the removal of the dresser from the handle until the moment of obtaining the required position, as it is given in Fig.11. When employing the lathe control system, it is necessary to read out a new position of the head (Fig. 9). In this case, the diamonds of the dressers are spaced at the distance of 110,25 mm.

When having information on the distance of zero point of operator in regard to X and Z axes from the selected measuring basis and knowing the mutual spacing of the dressers, it may be recognized that they are univocally set up in the workspace of the lathe. The grinded dressers, intended for precise profiling were employed. The producer declares the size and radius of the diamond. The obtained information should be considered in the further work on preparation of NC program. The process of profiling of grinding wheel is reverse in regard to standard turning, i.e. the tool remains immobile and the treated object is moved.

Summary

The presented method of measurements and setup of the tools enables the solution of the problems which may be encountered in the selected cases. It is the universal and inexpensive solution. Its application is supported by easiness and flexibility of assembly. Certainly, it will not replace the advanced and dedicated measurement systems. It may be ad hoc supplementation of their functionality. The application of unconventional solutions, being not provided by the producer in the constructions of their machines or equipment will usually result in the additional problems. The conducted studies prove that the presented problem as well as many others may be effectively solved. The advantage of the solution as regards the presented problem includes simplicity and easiness of the application. Additionally, in the case of a very precise treatment, especially of expensive elements, there is a possibility of verifying the state of the tools before the appearance of the undesired defects, resulting from the use of a worn or chipped edge.

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Projektujemy i wykonujemy urządzenia do montażu

- **elementów złącznych dla budownictwa:**
  - wkrętów farmerskich,
  - kołków rozporowych,
  - gwoździ z podkładką

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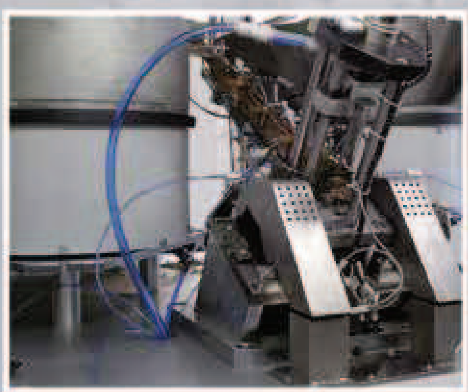

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ABSTRACTS:

1. sEMG-based shoulder-elbow composite motion pattern recognition and control methods for upper limb rehabilitation robot

Authors: Xiufeng Zhang, Jitao Dai, Xia Li, Huizi Li, Huiqun Fu, Guoxin Pan, Ning Zhang, Rong Yang, Jianguang Xu

This paper aims to develop a signal acquisition system of surface electromyography (sEMG) and use the characteristics of (sEMG) signal to interference action pattern.

This paper proposes a fusion method based on combining the coefficient of AR model and wavelet coefficient. It improves the recognition rate of the target action. To overcome the slow convergence speed and local optimum in standard BP network, the study presents a BP algorithm which combine with LM algorithm and PSO algorithm, and it improves the convergence speed and the recognition rate of the target action.

Experiments verify the effectiveness of the system from two aspects the target motion recognition rate and the corresponding reaction speed of the robotic system.

The study developed a signal acquisition system of sEMG and used the characteristics of (sEMG) signal to interference action pattern. The myoelectricity integral values are presented to determine the starting point and end point of target movement, which is more effective than using single sample point amplitude method.

2. Anti-disturbance iterative learning tracking control for space manipulators with repetitive reference trajectory

Authors: Jian Zhong Qiao, Hao Wu, Yukai Zhu, Jianwei Xu, Wenshuo Li

This paper is concerned with the repetitive trajectory tracking control for space manipulators under model uncertainties and vibration disturbances.

The model uncertainties and link vibration of manipulators will degrade the tracking performance of space manipulators; in this paper, a new hybrid control scheme that consists of a composite hierarchical anti-disturbance controller and an iterative learning controller is developed to solve this problem.

The composite hierarchical controller can effectively attenuate model uncertainties and reject vibration disturbances, whereas the iterative learning controller is able to improve the tracking accuracy for repetitive reference trajectory.

The proposed scheme compensates for the shortcomings of iterative learning control which can only deal with repetitive disturbances, ensuring the accuracy and repeatability of space manipulators under model uncertainties and random disturbances.

3. CurviPicker: a continuum robot for pick-and-place tasks

Authors: Zhixiong Yang, Bin Zhao, Liang Bo, Xiangyang Zhu, Kai Xu

Pick-and-place tasks are common across many industrial sectors, and many rigid-linked robots have been proposed for this application. This paper aims to alternatively present the development of a continuum robot for low-load medium-speed pick-and-place tasks.

An inversion of a previously proposed dual continuum mechanism, as a key design element, was used to realize the horizontal movements of the CurviPicker's end effector. A flexible shaft was inserted to realize rotation and translation about a vertical axis. The design concept, kinematics, system descriptions and proof-of-concept experimental characterizations are elaborated.

Experimental characterizations show that the CurviPicker can achieve satisfactory accuracy after motion calibration. The CurviPicker is easy to control due to its simple kinematics, while its structural compliance makes it safe to work with, as well as less sensitive to possible target picking position errors to avoid damaging itself or the to-be-picked objects.

The vertical translation of the CurviPicker is currently realized by moving the flexible shaft. Insertion of the flexible shaft introduces possible disturbances. It is desired to explore other form of variations to use structural deformation to realize the vertical translation.

The proposed CurviPicker realizes the Schöenflies motions via a simple structure. Such a robot can be used to increase robot presence and automation in small businesses for low-load medium-speed pick-and-place tasks.

4. Flexible co-manipulation and transportation with mobile multi-robot system

Authors: Bassem Hichri, Lounis Adouane, Jean-Christophe Fauroux, Youcef Mezouar, Ioan Doroftei

The purpose of this paper is to address optimal positioning of a group of mobile robots for a successful manipulation and transportation of payloads of any shape.

The chosen methodology to achieve optimal positioning of the robots around the payload to lift it and to transport it while maintaining a geometric multi-robot formation is presented. This appropriate configuration of the set of robots is obtained by combining constraints ensuring stable and safe lifting and transport of the payload. A suitable control law is then used to track a virtual structure in which each elementary robot has to keep its desired position with respect to the payload.

An optimal positioning of mobile robots around a payload to ensure stable co-manipulation and transportation task according to stability multi-criteria constraints. Simulation and experimental results validate the proposed control architecture and strategy for a successful transportation task based on virtual structure navigation approach.

This paper presents a new strategy for co-manipulation and co-transportation task based on a virtual structure navigation approach. An algorithm for optimal positioning of mobile robots around a payload of any mass and shape is proposed while ensuring stability during the whole process by respecting multi-criteria task stability constraints.

5. Docking mechanism design and dynamic analysis for the GEO tumbling satellite

Authors: Huang Jianbin, Li Zhi, Huang Longfei, Meng Bo, Han Xu, Pang Yujia

The paper presents a universal docking mechanism and force-limited Cartesian impedance control approach to capture the tumbling non-cooperative satellite. The docking mechanism was designed under-actuated to greatly reduce the difficulty of control and ensure the continuity, synchronization and force uniformity. The dynamic model of docking mechanism was established. The impact force was controlled within desired value by using a combination of active force-limited control approach and passive damping mechanism.

The mechanism includes a cone-rod mechanism which captures the apogee engine with a full consideration of despinning and damping characteristics and a locking and releasing mechanism which rigidly connects the international standard interface ring (Marman rings, such as 937B, 1194 and 1194A mechanical interface). The docking mechanism was designed under-actuated, aimed to greatly reduce the difficulty of control and ensure the continuity, synchronization and force uniformity under the process of repeatedly capturing, despinning, locking and releasing the tumbling satellite. The dynamic model of docking mechanism was established, and the impact force was analyzed in the docking process. Furthermore, a collision detection and compliance control method is proposed by using the active force-limited Cartesian impedance control and passive damping mechanism design.

6. Receding horizon control of mobile robots for locating unknown wireless sensor networks

Authors: Dilong Chen, Qiang Lu, Dongliang Peng, Ke Yin, Chaoliang Zhong, Ting Shi

The purpose of this paper is to propose a receding horizon control approach for the problem of locating unknown wireless sensor networks by using a mobile robot.

A control framework is used and consists of two levels: one is a decision level, while the other is a control level. In the decision level, a spatiotemporal probability occupancy grid method is used to give the possible positions of all nodes in sensor networks, where the posterior probability distributions of sensor nodes are estimated by capturing the transient signals. In the control level, a virtual robot is designed to move along the edge of obstacles such that the problem of obstacle avoidance can be transformed into a coordination problem of multiple robots. On the basis of the possible positions of sensor nodes and virtual robots, a receding horizon control approach is proposed to control mobile robots to locate sensor nodes, where a temporary target position method is utilized to avoid several special obstacles. When the number of obstacles increases, the average localization errors between the actual locations and the estimated locations significantly increase.

The proposed control approach can guide the mobile robot to avoid obstacles and deal with the corresponding dynamical events so as to locate all sensor nodes for an unknown wireless network.

7. Concurrent-learning-based visual servo tracking and scene identification of mobile robots

Authors: Yu Qiu, Baoquan Li, Wuxi Shi, Yimei Chen

The purpose of this paper is to present a visual servo tracking strategy for the wheeled mobile robot, where the unknown feature depth information can be identified simultaneously in the visual servoing process.

By using reference, desired and current images, system errors are constructed by measurable signals that are obtained by decomposing Euclidean homographies. Subsequently, by taking the advantage of the concurrent learning framework, both historical and current system data are used to construct an adaptive updating mechanism for recovering the unknown feature depth. Then, the kinematic controller is designed for the mobile robot to achieve the visual servo trajectory tracking task. Lyapunov techniques and LaSalle's invariance principle are used to prove that system errors and the depth estimation error converge to zero synchronously.

The concurrent learning-based visual servo tracking and identification technology is found to be reliable, accurate and efficient with both simulation and comparative experimental results. Both trajectory tracking and depth estimation errors converge to zero successfully.

On the basis of the concurrent learning framework, an adaptive control strategy is developed for the mobile robot to successfully identify the unknown scene depth while accomplishing the visual servo trajectory tracking task.

8. Mobile robot motion control and autonomous navigation in GPS-denied outdoor environments using 3D laser scanning

Authors: Qifeng Yang, Daokui Qu, Fang Xu, Fengshan Zou, Guojian He, Mingze Sun

This paper aims to propose a series of approaches to solve the problem of the mobile robot motion control and autonomous navigation in large-scale outdoor GPS-denied environments.

Based on the model of mobile robot with two driving wheels, a controller is designed and tested in obstacle-cluttered scenes in this paper. By using the priori "topology-geometry" map constructed based on the odometer data and the online matching algorithm of 3D-laser scanning points, a novel approach of outdoor localization with 3D-laser scanner is proposed to solve the problem of poor localization accuracy in GPS-denied environments. A path planning strategy based on geometric feature analysis and priority evaluation algorithm is also adopted to ensure the safety and reliability of mobile robot's autonomous navigation and control.

A series of experiments are conducted with a self-designed mobile robot platform in large-scale outdoor environments, and the experimental results show the validity and effectiveness of the proposed approach.

The problem of motion control for a differential drive mobile robot is investigated in this paper first. At the same time, a novel approach of outdoor localization with 3D-laser scanner is proposed to solve the problem of poor localization accuracy in GPS-denied environments. A path planning strategy based on geometric feature analysis and priority evaluation algorithm is also adopted to ensure the safety and reliability of mobile robot's autonomous navigation and control.

9. Unknown geometrical constraints estimation and trajectory planning for robotic door-opening task with visual teleoperation assists

Authors: Hongjun Xing, Kerui Xia, Liang Ding, Haibo Gao, Guangjun Liu, Zongquan Deng

The purpose of this paper is to enable autonomous door-opening with unknown geometrical constraints. Door-opening is a common action needed for mobile manipulators to perform rescue operation. However, it remains difficult for them to handle it in real rescue environments. The major difficulties of rescue manipulation involve contradiction between unknown geometrical constraints and limited sensors because of extreme physical constraints.

A method for estimating the unknown door geometrical parameters using coordinate transformation of the end-effector with visual teleoperation assists is proposed. A trajectory planning algorithm is developed using geometrical parameters from the proposed method.

The relevant experiments are also conducted using a manipulator suited to extreme physical constraints to open a real door with a locked latch and unknown geometrical parameters, which demonstrates the validity and efficiency of the proposed approach.

This is a novel method for estimating the unknown door geometrical parameters with coordinate transformation of the end-effector through visual teleoperation assists.

10. Position-based impedance force controller with sensorless force estimation

Authors: Jianjun Yuan, Yingjie Qian, Liming Gao, Zhaohan Yuan, Weiwei Wan

This paper aims to purpose an improved sensorless position-based force controller in gravitational direction for applications including polishing, milling and deburring.

The first issue is the external force/torque estimation at end-effector. By using motor's current information and Moore-Penrose generalized inverse matrix, it can be derived from the external torques of every joints for nonsingular cases. The second issue is the force control strategy which is based on position-based impedance control model. Two novel improvements were made to achieve a better performance. One is combination of impedance control and explicit force control. The other one is the real-time prediction of the surface's shape allowing the controller adaptive to arbitrary surfaces.

The result of validation experiments indicates that the estimation of external force and prediction of surface's shape are credible, and the position-based constant contact force controller in gravitational direction is functional. The accuracy of force tracking is adequate for targeted applications such as polishing, deburring and milling.

The value of this paper lies in three aspects which are sensorless external force estimation, the combination of impedance control and explicit force control and the independence of surface shape information achieved by real-time surface prediction.

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Z wyrazami szacunku i sympatii

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