

## RESEARCH OF SELECTED TECHNOLOGICAL FACTORS INFLUENCE ON ADHESIVE-BONDED JOINT PROPERTIES

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### **Abstract**

*The polymer-matrix composites have been applied to regeneration of machine elements since many years. Their properties as well as range of using are known generally. However, no exact comparative data about technological factors influence on the adhesive-bonded joints properties, especially the influence of surface preparation. Authors in view of the wide possibilities of the use of such composites in the repair of machinery and equipment, the issue of assessing the impact of technological factors on the properties of adhesive joints made in this work. In this paper was presented the results of adhesive-bonded joints researches depending on the preparation of adhesive material and the surface condition of jointed elements. The tests were selected most often used adhesive material. Based on these results it can be stated that the composition of the adhesive composition and condition of the surface preparation jointed elements have a significant influence on the properties of connections. It is noted considerable variation bonding strength between various variants of the state of the surface. The composition of the adhesive has a significant effect on the properties of the connection. Deficiency and excess hardener content in weight reduces the adhesive strength of the adhesive connection.*

**Keywords:** machine engines, adhesive-bonded joints, technological factors, regenerating adhesive composites

### **1. Introduction**

Only few of adhesive composition manufacturers were shared of knowledge and experience about utility properties of these materials. Very often given information are incomplete or simply laconic. Manufacturers dutiful about the users, next the typical materials data, they are given the details about the practical implementation of the technological process, and often are solved the resulting problems themselves. The constructor or technologist should know of which factors the strength of the adhesive-bonded joints depends on.

So far, there is a deficiency of precise analytical methods for calculating the strength of the adhesive-bonded joints.

Standard strength tests allow only to estimating the mechanical properties with general approximation. Undoubtedly, it is impediment to the constructor or technologist.

It is generally known, that there are a lot of physical, constructional and technological factors influence at adhesive-bonded joints strength. Analysed the range of adhesive composition application at regeneration should take into account such features as [1-9]:

- a) adhesive properties decisive about surface adhesion durability,
- b) cohesive properties decisive about composition material cohesive,
- c) mechanical properties decisive about strength ability,
- d) heighten temperature resistance,
- e) service fluids absorbed resistance,
- f) ageing resistance,
- g) abrasion and cavitation resistance,
- h) thermal conduction and no changing of cubical expansion during hardening,

i) producibility understood as easy using in repairs.

All of these above-mentioned factors are important for technologist. Among them we can find such those that are independent of technologist knowledge and experience, but also those that are highly dependent on its ability to. To the latter factors should be included adhesives properties, because adhesive strength of adhesive-bonded joints depending on composition adhesive properties but also on the accuracy of composition preparation, on type of bonded materials and a method of preparing the surface for bonding.

Technologist should also take into account the various constraints in the use of adhesive materials, including technological constraints, which the result from the no usability to hardening composition at low temperature of environment, necessity to accuracy and carefully preparation of composition (two-components compositions), different sensitivity composition on service fluids and type of surface materials influence. Economic constraints, which as results as relatively high purchase price of materials. Logistic constraints which as results as necessity of rotation these materials when you open and incomplete use of them, as a decrease utility properties of these materials stored in the longer period of time (especially after original packaging were opened to used small amount of materials). Logistic and safety constraints, which related to improvised repairs unconventional allowing for quick return of equipment for use.

## 2. Research methodology

The basic aim of the study was assessment of selected technological factors influence at the adhesive-bonded joints properties, with particular attention to the condition of surface preparation jointed elements and to prepare the adhesive composition. The researches were adhesive-bonded joints, most commonly used two-component adhesive for technological applications.

Test methods used were selected based on literature analysis and preliminary experiments to verify their availability, desirability and possibility of their application. The researches were made in accordance with the standards for surface preparation adhesive-bonded jointed elements and determining the shear strength at tensile joints, at standard samples prepared and tested under certain conditions [10; 11].

To achieve this objective of the work was awarded three research directions:

- the first – concerned the composition influence at the adhesive-bonded joints shear strength,
- the second - concerned the prepare methods of the jointed surface influence at the adhesive-bonded joints shear strength,
- the third – concerned the jointed materials type surface influence on the shear strength of adhesive-bonded joints.

For these cases, determine the change of mechanical properties, i.e. shear strength.

During the preparation of adhesive composition used the ratio of the weight, according the manufacturer requirements and in proportions differing by  $\pm 20\%$  from these requirements (accuracy of weighting 1 g). Differentiation proportions of base and hardener was connected with often used in technological conditions choice of components (base and hardener) based on a visual assessment of their volume.

## 3. Results of the investigations

### *The type and preparation of the adhesive composition*

The use of appropriate and carefully prepared the adhesive composition it is a basic condition to getting of adhesive-bonded joints high strength. Generally it was stated, that adhesive-bonded joint, formed from composition, must have physical properties similar physical properties of jointed materials and constructional requirements of joint. There is no universal adhesive. In addition, most importantly cannot be which is just as well all materials joining.

It is important to be prepared adhesive composition was homogeneous and had the right consistency. The hardener should be added to the adhesive composition closely keeping the

proportions specified by the manufacturer. Check whether the mixing of the components has been carried out properly is facilitated through the use of contrasting colours by the manufacturers of base and hardener. Adhesive composition should be mixed in such a way as to be free from streaks and local discolorations. In the workshop, especially in field conditions to prepare the adhesive can be difficult, especially for composition requiring very precise compliance with the proportions of the components. Available information shows that most of the materials available on the market have a significant tolerance in the selection of the components of the adhesive composition.

For example, at Fig. 1 it shows the composition of the adhesive composition influence on the shear strength of joint. Attempts strength of the adhesive bond shear was performed with 20% excess and deficiency of 20% hardener and also in the proportions recommended by the manufacturer. The obtained results show that a composition of the adhesive composition has a significant effect on the joint properties.

Excess 20% weight content of hardener in the adhesive composition it reduces the strength of the adhesive bond shear approx. 10% and deficiency 20% weight content it reduces the strength of the adhesive bond shear approx. 25%. It can be stated unequivocally that excess weight curing of the adhesive is less harmful than its deficiency.

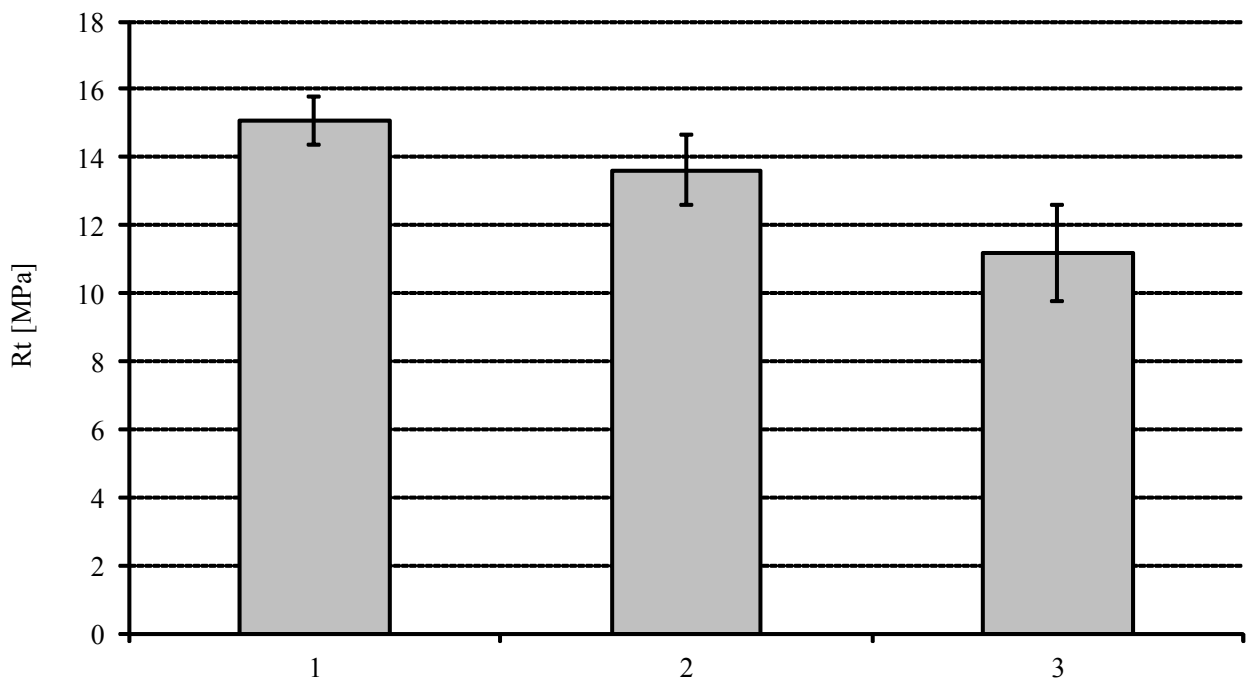


Fig. 1. The composition influence on the shear strength of adhesive-bonded joints: 1 – the composition recommended by the manufacturer; 2 – the composition with 20% increase of the hardener; 3 – the composition with 20% reduced of the hardener

Similarly, the negative behaviour of the tested properties of composite obtained leading other attempts, such as. Influence of ambient temperature on the reaction time or also the resistance of the composition to elevated temperature

Generally, it can be stated that the adhesive composition should preferably be prepared according to the manufacturer of adhesives, in clean containers, in rooms with low humidity and a temperature close to the nominal. It should be ensured to prepare it just before use. It should be ensured to not to exceed the acceptable lifetime of the adhesive composition. In the case of visual assessment of the composite components selection, it is preferable to add a bit more hardener than too little.

### Preparing the surface for bonding

Particular attention in the gluing process should be put on the proper preparation of the surface. It is an indispensable condition for obtaining high-strength adhesive connection. From the state of the joined surfaces, depends on the adhesive strength of the adhesive bond and, therefore, the overall strength of the joint.

Unfortunately, in technological practice it often happens that this operation is made by technical staff sometimes neglected. Hence, it derives many failures in the application of adhesive technology in the technology. These operations despite its simplicity should be done with great care even pedantic.

The glued surfaces should be clean and free of dust, dirt, old coatings and fats do not need to remind anyone. It is obvious that this kind of contamination is the number one enemy of the adhesion process. It is obvious that this kind of contamination is the number one enemy of the adhesion process. First of all, it must be ensured thorough surface degreasing, particularly the metals. Also for joining metals, it is recommended to remove from the surface of loosely related oxides by mechanical or chemical methods.

Cleanness of joining surface is a necessary condition but not sufficient to achieve a high joint strength. It is required to use special surface treatments, which are designed to increase physical activity joined surfaces. Most easily, uses are mechanical working: sandblasting, grinding or brushing with rotating wire brush. Satisfactory surface condition can be achieved by grinding the surfaces with suitable grain abrasive paper suitable grain. It should remember that after mechanical working degrease the surface thoroughly.

Mechanical adhesion theory assumes that the adhesive is anchored in the surface roughness. Sometimes excessive roughening the joined surface can reduce joint strength, because the adhesive composition, especially regenerating adhesive composition cannot fill and dampen cavities on the surface, which are intended to increase the physical activity.

In Fig. 2, it shows the effect of a method of surface treatment on the strength of the adhesive joint the shear; surfaces were degreased with agent recommended by the manufacturer.

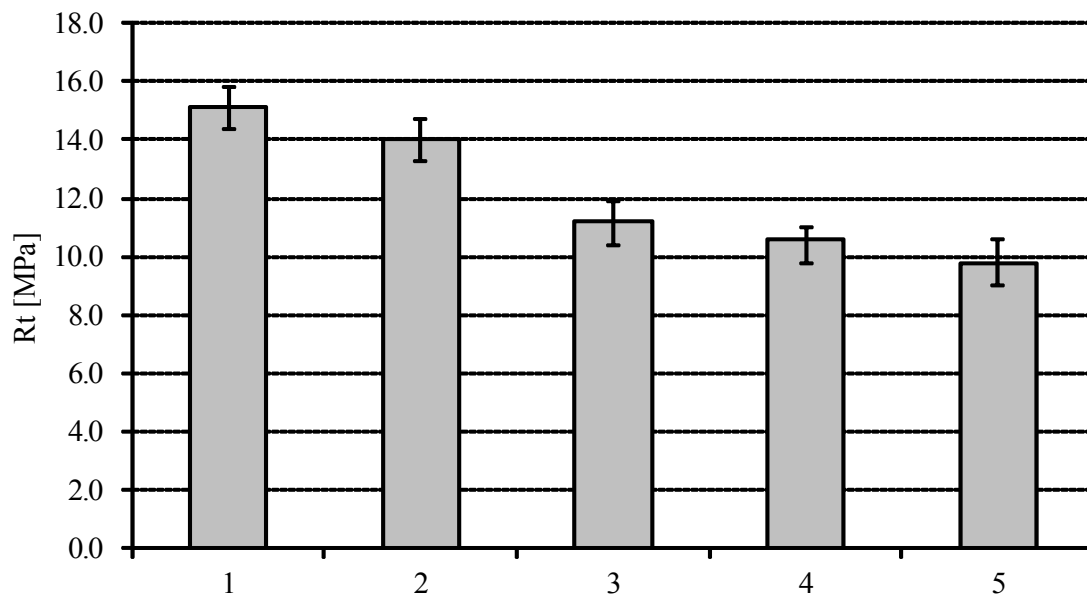


Fig. 2. Influence of the surface elements prepare way on the shear strength of adhesive-bonded joints: 1 – fine-grained corundum; 2 – coarse-grained corundum; 3 – 60 grit abrasive paper; 4 – 120 grit abrasive paper, 5 – 150 grit abrasive paper

The results showed that the method of preparation of the surface significantly influences the strength of the adhesive joint. Generally it can be stated, that joints whose surfaces were prepared using abrasive papers (three variants) they have significantly lower strength in comparison with joints whose surfaces were prepared using vapour blasting (sandblasting).

It also noted significant differences in the strength of connections between various variants of surface condition.

To ensure total cleanliness required in bonding elements is a matter quite difficult. When choosing how to surface prepare should also take into account the specificity of working conditions regenerated elements.

These problems are particularly pronounced when connecting elements susceptible to corrosion or treated salty environment for example seawater. In the latter case, after the abrasive blasting cleaning elements should stand at room temperature for a few hours. After precipitation salts on the outer surface of the cleaned again subjected to the sandblasting. Elements of hydraulic systems or elements in contact with the oil should be cleaned by firing radial before sandblasting. Good surface preparation effect is achieved by using needle vibrators, especially where because of safety or cannot use technology of sanding or grinding.

The research results indicate that the sandblasting agent is the most preferred corundum or copper slag 20-60  $\mu\text{m}$  grit, and if it is, use abrasive paper to prepare the steel surface – 60-120 grit paper.

In the last phase of surface preparation for bonding should take care of careful degreasing.

Shown in Fig. 3 changes characteristic in shear strength of adhesive joints, in depending on the degreasing agent type used for degreasing shows, that the most advantageous features are characterized by a joint strength after degreasing surfaces degreasing agent recommended by the manufacturer.

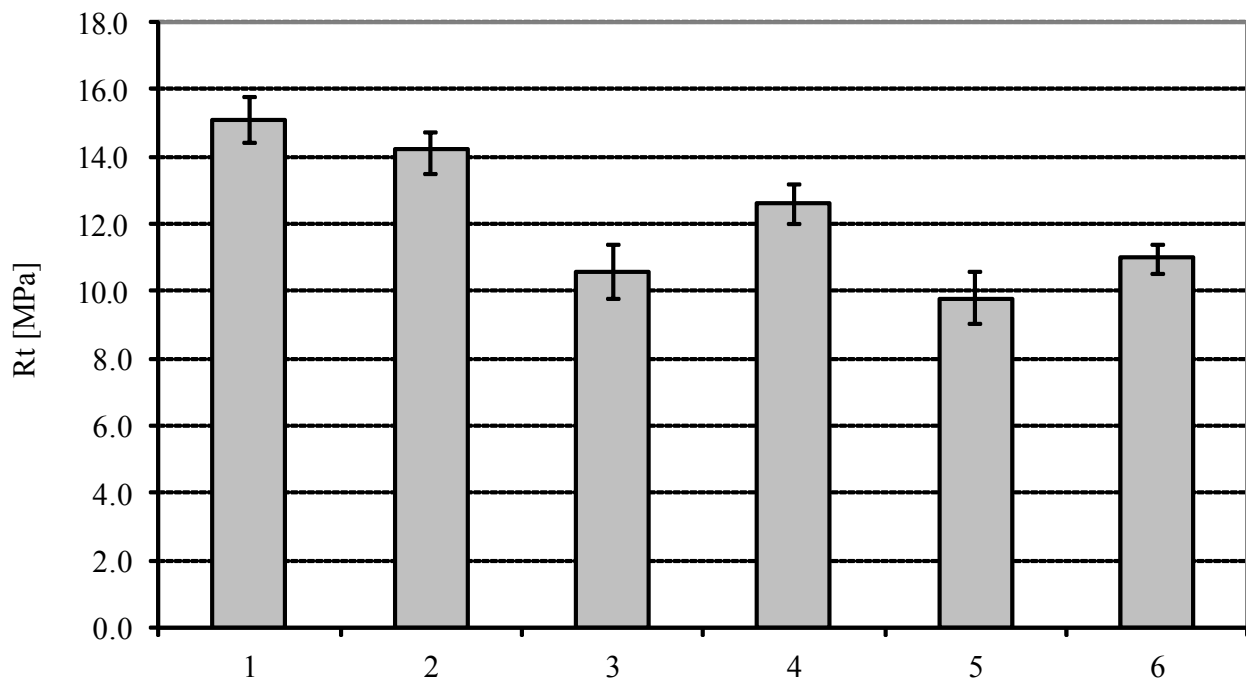


Fig. 3. Influence of degreasing agent type on the shear strength of adhesive-bonded joints (sandblasted surface): 1 – the agent recommended by the manufacturer; 2 – trichloroethylene 3 – acetone, 4 – ethyl acetate, 5 – extraction naphtha; 6 – solvent (70% toluene + 30% acetone)

When used for degreasing replacement agents can be expected to decline in the strength of joints. The smallest decrease in the joints strength of the adhesive shear strength was observed by using a degreasing trichloroethylene, the biggest decrease – using extraction naphtha. It should be noted that adhesive materials manufacturer does not recommend the use of extraction naphtha to degrease surfaces joined elements. This fact is imposed in that said agent it contains a few percent fatty fraction and strongly deteriorating properties of the joint. In practice, technological applications often get use to degrease surfaces glued elements alternative measures.

Generally, also known the type of surface material influenced at the mechanical properties of the adhesive-bonded joints. Made investigations clearly confirmed this issue (Fig. 4).

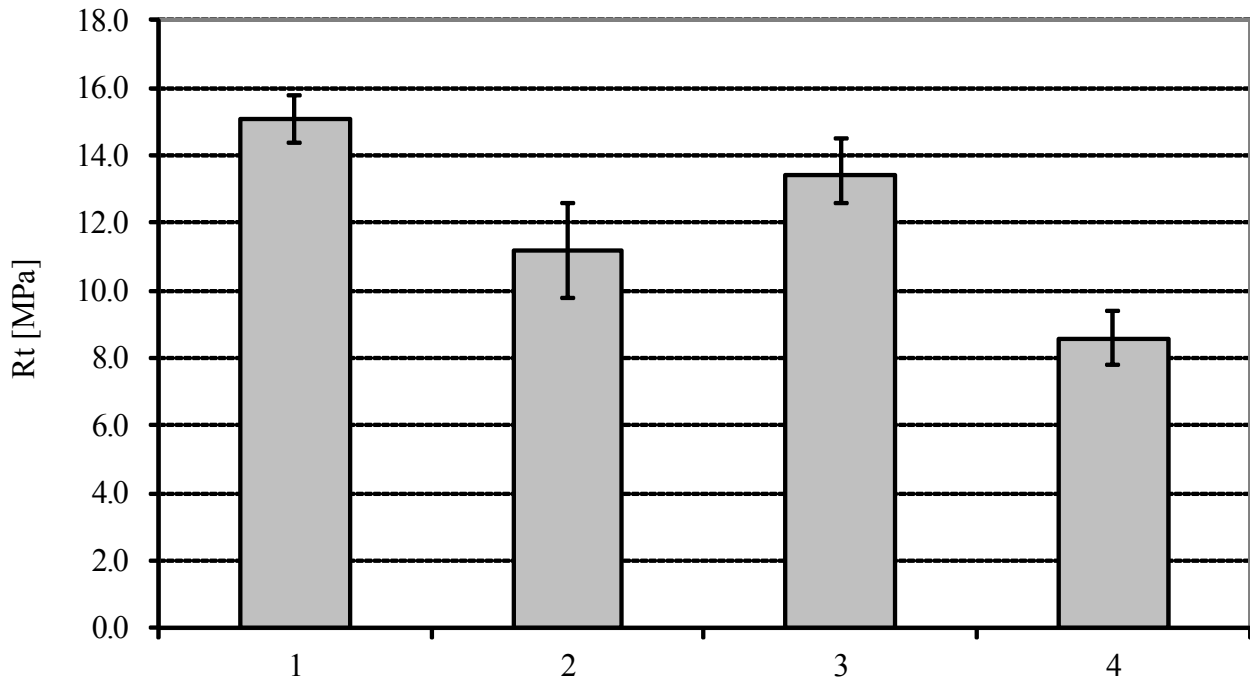


Fig. 4. Influence of jointed materials type on the shear strength of adhesive-bonded joints (sandblasted surface + degreased with the agent recommended by the manufacturer): 1 – medium-carbon steel; 2 – aluminium alloy; 3 – stainless steel; 4 – copper alloy

A comparison of the obtained results shows that the tested material shows a clear dependence of the shear strength of the surface material type. The highest strength had adhesive joints made of medium-carbon steel, the lowest strength – made of copper alloy.

Moreover, it should also be noted that not the behaviour of certain conditions of the composition hardening it could lead to a significant decrease in joint strength.

#### 4. The possibility and desirability assessment of the researched material using

Issues raised are not everything technological problems associated with the adhesive- bonding process; however, they are very important. There will be no exaggeration to say that it's not the kind of adhesive determines the properties of the joint, but above all proper and careful surface preparation for bonding and behaviour proportion between the base and hardener.

In summary, it must be stated, that the test material, due to its mechanical properties, taking into account the limitations of the investigations, it can be used in repair technology of machines and installations. This also applies to repairs carried out under field conditions.

Application range of test material can be wide, and above all, can be used to:

- cracks and voids of the material repair in the engine blocks, pump and filters casings, and gearboxes casings (provided that they do not transmit the tensile forces);
- regeneration of journal under rolling bearings and slide bearings;
- sealing joints;
- repair of tanks, metal pipes and tubes;
- repair of technological connections and selected construction joints.

## **5. Conclusions**

With generalizations presented the research results of selected the polymer matrix composite, it can draw the following conclusions:

- the composition of the adhesive composition has a significant effect on the properties of the connection; deficiency and excess hardener content in adhesive composition reduces the shear strength of the adhesive joints in relation to the proportion of the components specified by the manufacturer of adhesive;
- these results show that the method of surface preparation significantly influence the strength of the adhesive connection; it can be stated, that joints whose surfaces were prepared using abrasive papers (three variants) they have significantly lower strength in comparison with joints whose surfaces were prepared using vapour blasting (sand-blasting);
- the results confirm the literature data, that the use to the degreasing of alternative agents associated with decreased strength of the joints; the smallest decrease in the joints strength of the adhesive shear strength was observed by using a degreasing trichloroethylene, the biggest decrease - using extraction naphtha;
- comparison of the results shows, that the test material has a clear dependence of the shear strength of the surface material; the highest strength had adhesive joints made of medium-carbon steel, the lowest strength - made of copper alloy;
- there is a need for further research, in order to determine other properties of adhesive-bonded joints, influence on strength bonded joints and not specified by the manufacturer in advertising materials.

## **References**

- [1] Cypko, E., Kowalczyk, S., Raczkowski, D., *Naprawa sprzętu wojskowego z zastosowaniem materiałów szybkowiążących*, SG WP, Sł. Techn., nr 158/97, Warszawa, 1998.
- [2] Cypko, E., Kowalczyk, S., Smal, T., *Zmiany właściwości regeneracyjnego materiału kompozytowego pod wpływem czynników starzeniowych*. Mezhdunarodnaia nauchno-prakticheskaya konferenciya „Progress transportnykh sredstv i sistem”, Volgograd, 1999.
- [3] Kowalczyk, S., *Badanie właściwości kompozytowych materiałów regeneracyjnych w aspekcie ich zastosowań w obiektach pływających i portowych*, Zeszyty Naukowe nr 66 Wyższej Szkoły Morskiej, Szczecin, 2002.
- [4] Kowalczyk, S., Raczkowski, D., *Materiały kompozytowe – Wpływ czynników technologicznych na własności połączeń*. Krajowa Konferencja Naukowo-Techniczna. Szczecin`97, Świnoujście, 1997.
- [5] Kowalczyk, S., Smal, T., *Wpływ czynników środowiskowych na zmiany właściwości kompozytu regeneracyjnego*. V Krajowa Konferencja "Regeneracja`98", Bydgoszcz, 1998.
- [6] Kowalczyk, S., Smal, T., *Metodyka i wyniki badań klejowych kompozytów regeneracyjnych*, Biuletyn WAT, Nr 10, Warszawa, 2000.
- [7] Kowalczyk, S., Smal, T., *Badanie odporności kompozytowych materiałów regeneracyjnych na starzenie*. W: Nowe materiały – nowe technologie w przemyśle okrętowym

- i maszynowym: konferencja naukowo-techniczna, Szczecin-Świnoujście 10-13.09.1998: Materiały konferencyjne, Szczecin: PPH ZAPOL, T.1, 1998.
- [8] Kowalczyk, S., Cypko, E., Smal, T., *Uwarunkowania technologiczne stosowania kompozytów klejowych*. Kielce, 2000.
- [9] Kowalczyk, S., Raczkowski, D., Właściwości technologiczne kompozytów regeneracyjnych. Przegląd spawalnictwa, Nr 11, 1997.
- [10] PN-EN 13887:2005: *Kleje do połączeń konstrukcyjnych - Wytyczne do przygotowania powierzchni metali i tworzyw sztucznych przed klejeniem*.
- [11] PN-EN 1465:2009: *Kleje - Oznaczanie wytrzymałości na ścinanie przy rozciąganiu połączeń na zakładkę*.