PRELIMINARY EXAMINATIONS OF IMPACT STRENGTH OF ADHESIVE LAP JOINTS

Badania wstępne udarności połączeń klejowych zakładkowych

Начальные исследования ударности нахлестковых клеевых соединений

Andrzej KOMOREK ORCID: 0000-0002-2293-714X
Jan GODZIMIRSKI ORCID: 0000-0003-1593-2057
Damian CHODURSKI
Roman PNIEWSKI ORCID: 0000-0002-8481-193X
DOI: 10.15199/160.2019.4.2

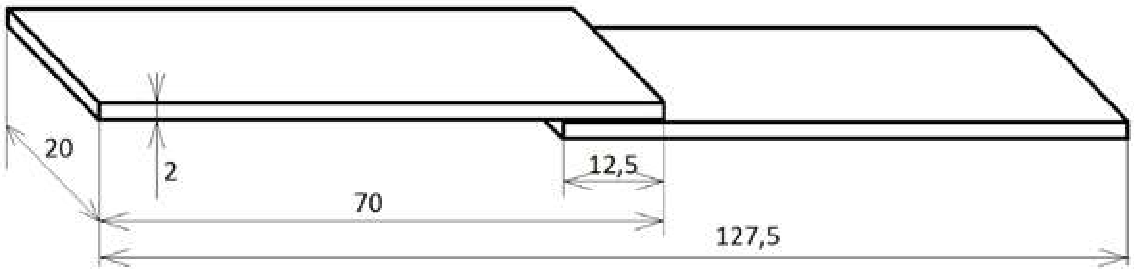
A b s t r a c t: The research into the impact strength of adhesive joints has been carried out since the 1980s, however, so far no universal method has been developed so as to ensure obtaining useful results. The article presents the authors' own methodology of investigating the impact strength of adhesive 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.
K e y w o r d s : adhesive joint, impact strength, pendulum hammer
S t r e s z c z e n i e: 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.
S ł o w a   k l u c z o w e : 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.

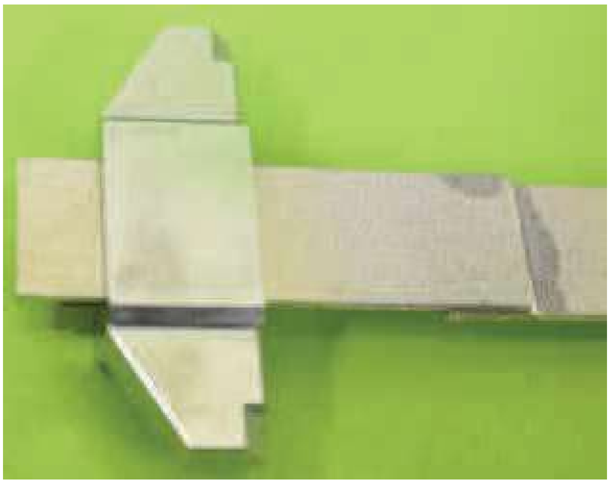
Fig. 2. Pendulum hammer Julietta
Rys. 2. Młot wahadłowy Julietta

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



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).

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

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

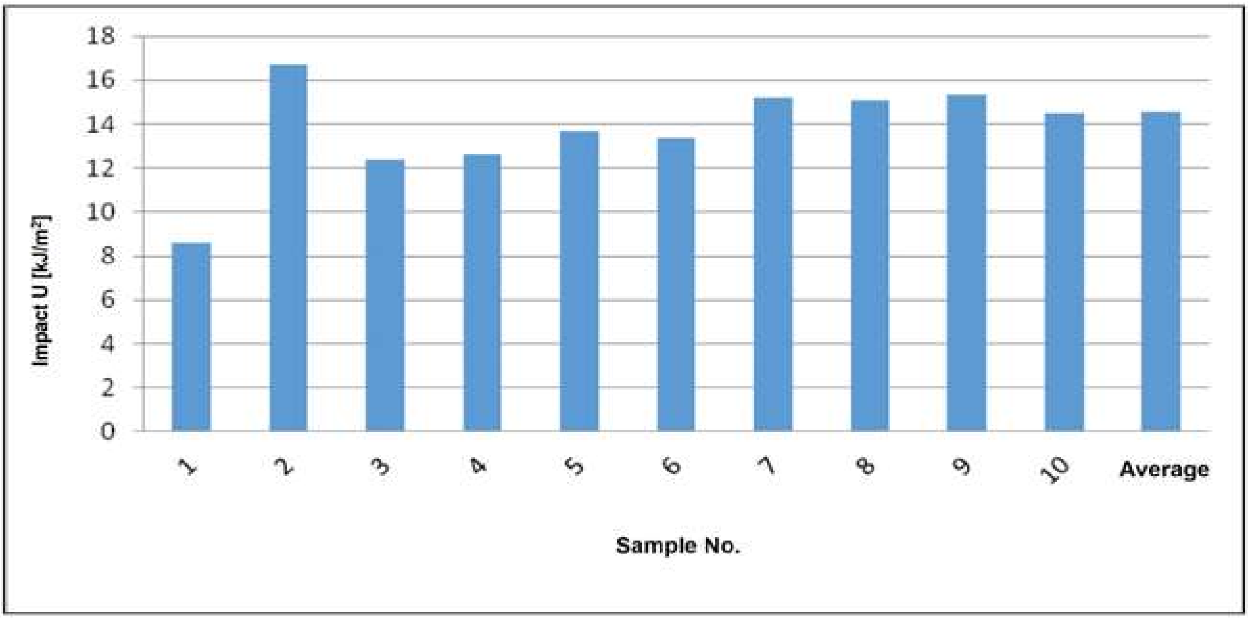
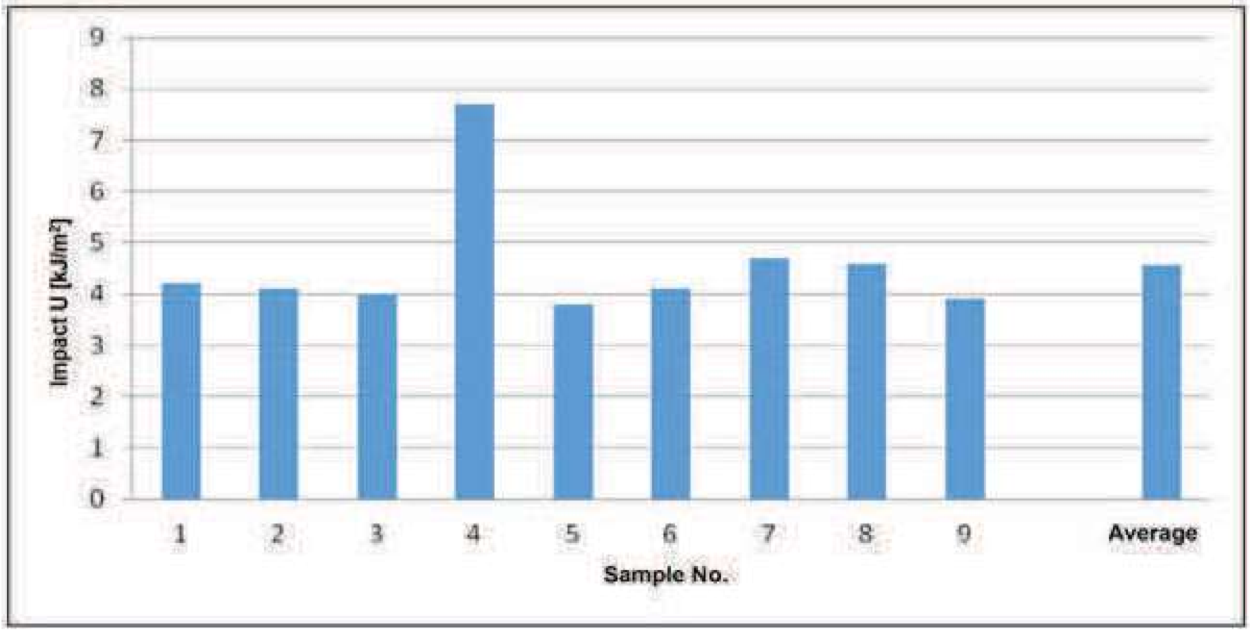


Fig. 6. Impact strength of samples of aluminum alloy 2017A joined with Loctite 9492
Rys. 6. Udarność próbek ze stopu aluminium 2017A przy zastosowaniu kleju Loctite EA 9492



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.

References

[1] Adams R.D., J.A. Harris. 1996. “A critical assessment of the block impact test for measuring the impact strength of adhesive bonds”. International Journal of Adhesion and Adhesives (16): 61-71.

[2] Casas-Rodriguez J.P., I.A. Ashcroft, V.V. Silberschmidt. 2007. “Damage evolution in adhesive joints to impact fatigue”. Journal of Sound and Vibration (308): 467-478.

[3] Goglio L., M. Rosetto. 2008. “Impact rupture of structural adhesive joints under different stress combinations”. International Journal of Impact Engineering (35): 635-643.

[4] Karachalios E.F., R.D. Adams, L.F.M. da Silva. 2013. “Single lap joints loaded in tension with ductile steel adherends” International Journal of Adhesion and Adhesives (43): 96-108.

[5] Komorek A., P. Przybyłek. 2015. "Initial research of impact strength in adhesive joints". Solid State Phenomena, Vol. 237: 160-165.
[6] Komorek A. i in. 2018. „Wpływ wartości współczynnika sprężystości wzdłużnej kleju na udarność połączeń klejowych blokowych". Technologia i Automatyzacja Montażu (3): 53-58.
[7] Machado J.J.M. et. al. 2018. "Numerical study of impact behaviour of mixed adhesive single lap joints for the automotive industry". International Journal of Adhesion and Adhesives (84): 92-100.
[8] PN-ISO 9653 – Kleje. Metody badania wytrzymałości na ścinanie udarowe połączeń klejowych 2000.
[9] Sato C. 2005. "Impact behavior of adhesively bonded joints". in: Adhesive Bonding: Science, Technology and Applications, pod red. Adams R.D. WPL, Cambridge: 64-188.
[10] Taylor A. 1996. "Impact Testing of Adhesive Joints". MTS Adhesive Project 2 AEA Technology, 5 (2).
[11] Viana G. et. al. 2018. "Strain rate dependence of adhesive joints for the automotive industry at low and high temperatures". Journal of Adhesion Science and Technology 32:19, 2162-2179.

prof. Jan Godzimirski, Ph.D., Eng. - Institute of Aviation, in the Department of Mechatronics and Aviation at the Military University of Technology in Warsaw, address: Gen. S. Kaliskiego 2 Street, 00-908 Warszawa, e-mail: jan.godzimirski@wat.edu.pl

Assoc. Prof., Eng. Roman Pniewski - Institute of Automatics and Telematics in the Faculty of Transport and Electrical Engineering, at the University of Technology and Humanities in Radom in Radom, address: Malczewskiego 29 Street, 26-600 Radom, e-mail: r.pniewski@uthrad.pl

Assoc. Prof., Eng. Andrzej Komorek - Department of Avionics and Control Systems, in the Faculty of Aeronautics, of the Air Force University in Dęblin, address: Dywizjonu 303 Street, no 35, 08-521 Dęblin, e-mail: komman@op.pl

MSc, Eng. Damian Chodurski - graduate of the Aeronautics Faculty of the Air Force University in Dęblin, e-mail: d.chodurski@wsosp.edu.pl