Adhesive technology in the automotive industry

Janette Brezinová[1], Henrich Sailer[1]
Faculty of Mechanical Engineering, Technical university of Kosice, Slovakia[1]
janette.brezinova@tuke.sk henrich.sailer@tuke.sk

Abstract: *The paper presents the results of the research focused on the determination of the quality of adhesive joints of cold rolled sheets in the automotive industry. DC05 galvanized sheet was used for joints. A progressive type of adhesive used in the automotive industry was chosen. The shear and peel strength of the adhesive joints according to Winter were determined. The strength of the joints was determined depending on the cure temperature of the adhesive. After tests, the character of fracture surfaces of adhesive joints was evaluated.*
KEYWORDS*: ADHESION, COHESION, SHEAR STRENGTH, PEEL STRENGTH*

1. Introduction

Gluing technology is nowadays a very widespread method of joining materials that can be encountered in perhaps all industrial sectors. Especially in the automotive industry, they are increasingly used adhesives, which, in contrast to conventional methods of joining materials, offer a range of advantages, especially in multi-layer body parts. In the automotive industry, great emphasis is placed on safety, reliability, quality, comfort and, of course, the price of the car. Bonding in this In this case, it provides optimal rigidity of the structure while reducing weight. This technology is often the only joining technique materials that do not damage the jointed surface and allow the connection of different materials such as glass, aluminum, plastic or steel sheets that are possible easily and safely combined to obtain such shapes and properties as they would with other technologies were difficult to achieve. In the case of gluing technology in the automotive industry, there is a difference bonding of lubricated surfaces. Because in the automotive The industry uses gluing technology without degreasing, it must be current adhesives used in the automotive industry, able to create required glued body joint, even with the use of lubricant. As material requirements continue to increase, they are dealing with leading sheet metal manufacturers in cooperation with car manufacturers developing new ones surfaces that would improve the tribological properties when pressing body parts. [1]

Bonding materials is very common nowadays technological method, for example in the automotive industry, where this was technology previously used only as ancillary. Today in some cases replaces traditional methods of structural joining of materials. If it will need to decide whether to use gluing technology or to prefer some From other technological methods of joining materials, it is important to know the conditions to which the connection will be exposed and the characteristics of the individual technologies joining materials, as none of the joining technologies has just advantages, but we also find disadvantages that need to be taken into account [2].

The most important advantage of glued joints in comparison with conventional joints is the increase in the overall strength of a suitably designed joint. When riveting and screwing, the holes reduce the cross-section of the joined parts and, in addition, cause a high concentration of stress, so that the joined material cannot be used for strength. The strength advantages of glued joints over welding are not always as clear-cut as when compared to riveting and screwing. In addition to the structural arrangement and the type of load, the material to be joined is of essential importance [3]. In the following Figure 1. a comparison of voltage waveforms in the already mentioned joints is given.

Advantages of glued joints

With riveting or screwing technology, two materials with different electrochemical potentials may come into metal contact and a galvanic cell is formed in a corrosive environment (for example, unsuitable weather conditions).

When realizing glued joints, it is possible to use thinner materials in terms of even stress distribution, and thus reduce weight.

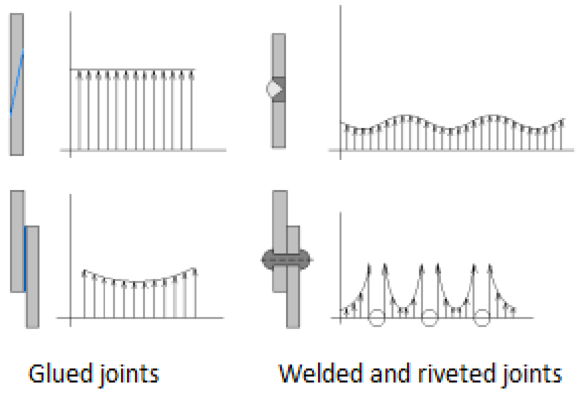


Figure 1. Stress profile in connections [5]

Bonding makes it possible to join almost most materials, including those that are non-weldable under normal conditions or have unsatisfactory strength after welding, but also those that are difficult to machine, rivet or join screws. Last but not least, only the gluing technology allows the force to be evenly distributed along the entire length of the joint.

With miniaturized components, it is often not possible to use classical methods, as rivets, screws or welds cannot be reduced indefinitely. In this case, the solution could be gluing, which does not cause local heating, as is the case with welding. The parts do not collapse and the properties are not affected.

Unlike conventional methods of joining materials, gluing ensures the tightness of the joint along its entire length, not just at certain points. It is therefore not necessary to additionally seal the glued joints (this also applies to fuel tanks). The adhesive layer acts as an insulator and separates the two parts. The sheets do not knock and the noise is reduced.

When joining materials by gluing, the base material is not affected, such as the jet in welding, in which a heat-affected area having a different structure than the base material is located near the weld.

Disadvantages of glued joints

When designing a glued joint, it is better to give priority to the construction of the joint on

shear stress if structurally possible, as its low peel strength must be taken into account. Otherwise, welding, screwing or riveting will ensure better conditions.

Another disadvantage of glued joints is low resistance at high temperatures. If the adhesive is not designed to work at higher temperatures, it loses its strength. Adhesives cured around 160 °C retain their properties for short periods (approx. 1 h) at temperatures up to 220 °C. At the same time, if the glued joints are exposed to static loads at higher temperatures, there is a risk of creep.

Most of the construction adhesives used are for strength need to harden. The curing time is usually dependent on the curing temperature. The higher the curing temperature, the shorter the curing time, which can be from a few minutes to several hours. This means that glued joints never reach instantaneous strength, as with other technologies such as screwing.

The disadvantage of glued joints is in most cases the need for surface treatment (degreasing, removal of mechanical impurities, surface roughening, etc.), which is essential for the strength of the joint. The complexity of surface treatments will therefore depend on the type of adherend and the required strength.

One of the disadvantages of gluing compared to joining materials by screwing is impossibility of later modifications.

The paper presents the results of the research focused on the determination of the quality of adhesive joints of cold rolled sheets in the automotive industry. [4]

2. Materials and methodology of experiments

The aim of the experimental work was to determine the strength of glued joints depending on the curing temperature of the adhesive used. A progressive type of adhesive used in the automotive industry was chosen. The shear strength and peel strength were determined according to Winter. After the tests, the appearance of the fracture surfaces was evaluated. The test specimens were cut from cold-rolled galvanized deep-drawn steel DC05 from cold-formed steel. The thickness of the Zn layer was cut from 50 to 190μm and was applied by hot-dip galvanizing technology. Table 1 lists the chemical composition and mechanical properties of the material. [5]

Table 1: *Mechanical properties and chemical composition of material DC05*

	Chemical composition [Weight %]	Mechanical properties
C_{max}	0.06	
Mn_{max}	0.35	
P_{max}	0.025	
S_{max}	0.025	
Yield strength $Rp_{0.2}$ [MPa]		180
Ultimate tensile strength Rm [MPa]		270-330
A_{MIN} [%]L_0=80mm		40
r_{90} min.		1.9
n_{90} min.		0.2

Table 2: *Mechanical properties of Stainless steel, Martensitic steel, Bronze-nickel alloy*

	Stainless steel EOS GP1	Martensitic steel EOS MS 1	Bronze-nickel alloy DM 20
Min. wall thickness [mm]	0.4	0.4	0.6
Speed of fabrication [mm^3/min]	2-5	2-4	10-20
Residual porosity [%]	-	-	8%
Yield strength Ultimate tensile strength Rm [MPa]	900	1100 (1950*)	400
Proof stress Rp0,2 [MPa]	500	1000 (1900*)	200
Modulus of elasticity [GPa]	190	180	80
Abrasive hardness	23-33 HRC	36-39 (50-54*) HRC	120 HV
Max. working temp. [°C]	550	400	400

The contact surfaces of the glued joints were degreased with technical gasoline and subsequently the surface roughness was evaluated. A Mitutoyo Surftest SJ-301 profilometer was used to determine the surface roughness. The roughness measurement was in accordance with the ISO 11 339 standard, the value of Ra (mean arithmetic deviation) and Rz (highest profile height) was determined.

Table 2: *Parameters for measuring the surface roughness of contact surfaces*

Basic length	*(λ_c)=2.5mm*
Number of basic lengths	*N=5*
Measured profile	*R (middle line system)*
Filter	*Gauss*
Evaluated length	*ln= 12.5 mm*

Used adhesive - Terokal-8026GB-25 henkel. It is a one-component adhesive for metal, which hardens when hot in the range of 160 - 220 ° C. It contains glass beads with a diameter of 90-150 μ, which ensure the required thickness of the adhesive. Table 3 lists the technical data of the adhesive. The thickness of the adhesive was 0.2 mm. The joints were secured against misalignment. [9]

Table 3: *Technical specifications*

Color:	Light blue	
Density:	1.53 g/cm^3	
Dry:	>99%	
Adhesiveness:	Good bond on greased and galvanized raw sheet, as well as on aluminum sheet	
Elasticity:	Tough elastic	
Corrosion resistance:	Without undercorrosion and loss of adhesion	
Shear strength:	>2.8 MPa	
	At room temperature	
	At 90 °C	>12 MPa cohesive
	At -35 °C	>7 MPa cohesive
E-modul:	700 MPa	>15 MPa cohesive
Transverse contraction:	0.4	
Sheet thickness:	0.8 mm	
Temperature of use:	-40 – 80 °C	

The evaluated joints were cured at 140 °C, 160 °C, 180 °C, 200 °C and 220 °C for 30 min and then cooled to room temperature.

Determination of shear strength of interlaced glued joint under tensile stress ISO 4587

This European Standard specifies a method for the determination of the tensile shear strength of interlaced adhesive systems. The test is performed on standard test equipment under prescribed preparation and testing conditions. The essence of the test is the shear stress of the tested joint by static tension in the direction of the longitudinal axis until the failure of the specimen.

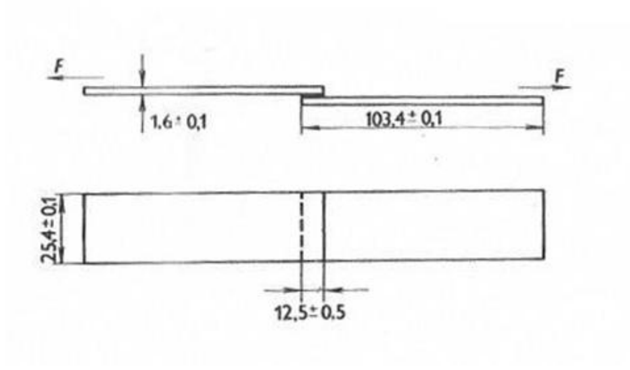


Figure 2. *Sample shape for shear strength test according to ISO 4587*

Test in peeling of glued systems from flexible adherends EN ISO 11339

This European Standard is used to determine the strength of adhesives used in the assembly of two flexible adhesives. The test is performed using T-shaped test specimens, fig. 17. The test evaluates the maximum and mean peel force in N mm^{-1} according to the relations:

$$PA = FA / b$$

$$PS = FS / b$$

where PA is the initial (absolute) peel strength in N mm^{-1} of the sample width,

FA - maximum force in N

b - width of the glued joint

PS - average peel strength in N mm-1 of sample width

FS - average force in N, which is calculated by planimetrizing the area of the diagram in the range of 30 to 90% of the length of the whole diagram [7, 8, 9].

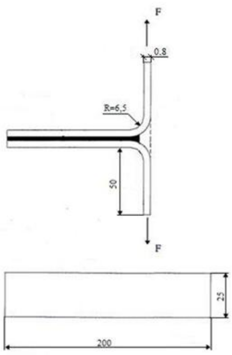


Figure 3. *Sample shape for strength test according to EN ISO 11339*

All tests were performed on the Tiratest 2300 rupture tester and the samples were cured in the Ecocell oven. The loading rate of the samples was 100 mm min^{-1}.

Peel strength according to Winter (66 8516) - modified test

The essence of the test is the stress of the tested joint by peeling by static tension in the direction perpendicular to the bonded surface. Peel strength means the force in N mm^{-1} of the width of the sample required to separate the two bonded surfaces according to Figure 4. which is given by two values:

$$ϬWA = FA / b$$

$$ϬWS = FS / b$$

where ϬWA is the initial (absolute) peel strength in N mm^{-1} of the sample width,

FA - maximum force in N

b - width of the glued joint

ϬWS - average peel strength in N mm-1 of sample width

FS - average force in N, which is calculated by planimetrizing the area of the diagram in the range of 30 to 90% of the length of the whole diagram [10, 11, 12].

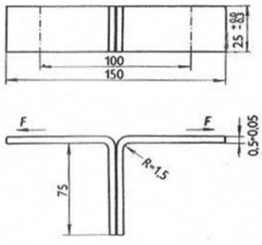


Figure 4. *Sample shape for Winter peel strength test*

The evaluation of the fracture surfaces of the glued joint on the samples was determined according to the standard STN EN ISO 10365.

3. Achieved results

The microgeometry of the used adherend was evaluated on the contact surfaces of the glued joints. The evaluated parameters were Ra and Rz, with Ra = 1.24 am and Rz = 5.70 µm.

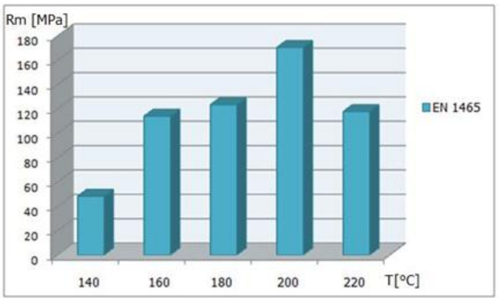


Figure 5. *Comparison of the joint strength of the STN EN 1465 test depending on the curing temperature of the adhesive*

Figure 5. shows the tensile shear strengths of interlaced glued joints. The joints reached the highest strength value at a curing temperature of 200 °C.

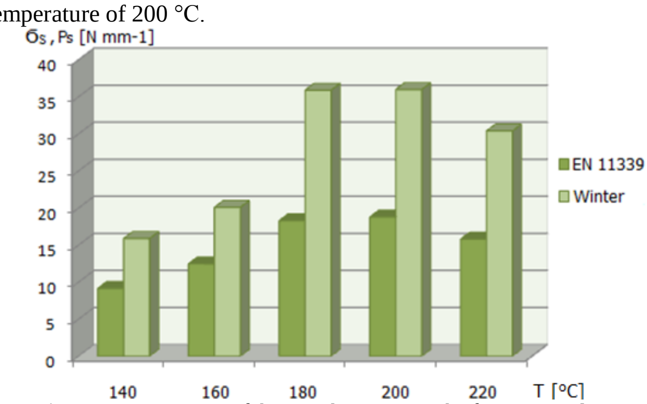


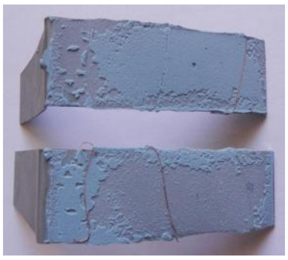
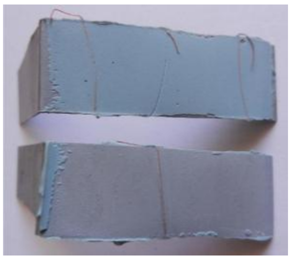
Figure 6. *Comparison of the initial joint strength of tests according to Winter and ISO 11339 depending on the curing temperature of the adhesive*

Figure 6. presents a comparison of the shear strength of adhesive joints in peeling (test according to Winter and EN ISO 11339). The initial strength values are higher in the Winter test due to the size of the bonded area, the shape of the specimens and the

method of stress. As the tested adhesive is thermochromic, this was also reflected in a change in the color of the adhesive. After evaluating the type of fractures, cohesive fracture predominated. In the formation of joints with a curing temperature of 220 °C, the adhesive was degraded by the formation of pores and bubbles, which negatively affected the integrity of the adhesive layer and consequently reduced joint strength. After the destruction tests, the fracture surfaces of individual joints were evaluated.

The appearance of the quarry areas and the type of quarries are given in Table 4.

***Table 4**. Fracture type at curing temperature 140 – 200 °C*

 Adhesive curing temperature 140 °C	 Adhesive curing temperature 160 °C
 Adhesive curing temperature 180 °C	 Adhesive curing temperature 200 °C

4. Conclusion

The experimentally obtained results confirmed that the adhesive Terokal 8026GB-25 showed the highest strength of bonded steel materials with a zinc layer at a curing temperature of 200 °C in all tests. As the curing temperature increases, its strength decreases. The adhesive was already cured at 140 °C. However, the results showed that at this temperature the joint shows low strength and the character of the fracture surfaces is mostly cohesive and has an asymmetrical structure. The highest shear strength was achieved by the interlaced glued joint at a curing temperature of 200 °C, at higher temperature the strength of the joint decreased.

When testing the joints for peel strength according to EN ISO 11339, it was found that although both methods have the same test principle, the Winter test showed an approximately 50% higher peel strength value. These differences were due to the different dimensions of the contact surfaces of the test specimens and the geometry of the specimens. The tested adhesive is ermochromic, which manifested itself in a change in the color of the adhesive. After evaluating the type of quarries, a cohesive quarry prevailed. During the formation of joints with a curing temperature of 220 °C, the adhesive was degraded by the formation of pores and bubbles, which had a negative effect on the integrity of the adhesive layer and consequently a reduction in the strength of the joint.

Acknowledgments: This work was supported by scientific grant agency of the Ministry of Education of the Slovak Republic VEGA No. 1/0154/19 and KEGA 001STU-4/2019.

4. References

1. Unsere Geschichte, unsere Zukunft [online]. [cit. 2013-02-03]. Available on the Internet: <http://www.tesa.de/industry/automobilindustrie/ueber_uns/unsere_geschichte_unsere_zukunft>
2. What is tesa ACX [online]. [cit. 2013-02-03]. Available on the Internet: <http://www.tesa-acxplus.com/eng/eigenschaften/technoloy>
3. Stress Dissipation [online]. [cit. 2013-02-03]. Available on the Internet: <http://www.tesa-acxplus.com/eng/eigenschaften/stress_dissipation>
4. Speiegelherstellung [online]. [cit. 2013-02-10]. Available on the Internet: <http://www.tesa.de/industry/automobilindustrie/exterieur/spiegelherstellung>
5. What is tesa ACX [online]. [cit. 2013-03-01]. Available on the Internet: <http://www.tesa-acxplus.com/eng/eigenschaften/technoloy>
6. THYSSENKRUPP STEEL EUROPE.: Forming made easy. Available on the Internet: <http://www.thyssenkrupp-steel-europe.com/tiny/3cR/download.pdf>
7. A. KAYA:.Effects of various parameters on dynamic charakteristics in adhesively bonded joints, Materials Letters 58 (2004) 3451–3456.
8. F. TAHERY: Influence of adherend´s delamination on the response of single lap and socket tubular adhesively bonded joints subjected to torsion, Composite Structures 93 (2011) 1765–1774.
9. D. CASTAGNETTI: Failure analysis of bonded T - peel joints: Efficient modeling by standard finite elements with experimental validation, International Journal of Adhesion & Adhesives 30 (2010) 306–312.
10. Itw Plexus - Structural Adhesives [online]. [cit. 2007-05-08] Available on the Internet: <http://www.itwplexus.co.uk/es/products/guidebond.html>
11. The influence of nanoadhesives…[online]. [cit.2008-8-3]. Available on the Internet: <http:// www.sciencedirect.com
12. EF. Karachalios: .Single lap joints loaded in tension with high strength steel adherends.IntJ Adhes Adhes 2013;43:81–95.