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Mechanical Properties of Adhesive Joints Made with Pressure-Sensitive Adhesives

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The paper aims to determine the mechanical properties of the adhesive joints made with acrylic pressure-sensitive adhesives. Two types of double-sided acrylic pressure-sensitive adhesive tapes are used. Three construction materials are used to prepare the adhesive joints: structural steel sheet (C45), aluminium alloy sheet (EN-AW 5754), and titanium sheet (Grade 2). Strength tests of adhesive joints made with the pressure-sensitive adhesive tapes are carried out both after conditioning time at room temperature (23 °C) and subjected to thermal shocks (500 cycles: +60 °C / –40 °C). Strength tests are carried out based on the DIN EN 1465 standard on a Zwick/Roell Z150 testing machine. The main conclusion from the tests carried out was the positive effect of thermal shocks on the mechanical strength of joints bonded with pressure-sensitive adhesive tape.
Keywords: adhesive joint, pressure-sensitive adhesive, mechanical properties, thermal shocks

Highlights
- *In the investigated range of the thermal shocks, the post-conditioning does not appear to trigger the deterioration of the mechanical properties of the adhesive joints bonded with the pressure-sensitive adhesive tapes.*
- *The increase in the adhesive joints' strength is also associated with the type of adherend.*
- *There is a positive correlation between the thermal shocks and the mechanical strength of the adhesive joint bonded with the pressure-sensitive adhesive tapes.*
- *The pressure-sensitive adhesive tapes exhibit a good capacity for bonding the considered adherends under the considered conditions.*

0 INTRODUCTION

Assembly joints can be made using various joining methods, including bonding [1] to [3]. One type of adhesive material used in assembly processes is pressure-sensitive adhesives. Pressure-sensitive adhesive tape is an alternative to conventional mechanical joining methods, including screws, rivets, dowels and other fasteners. In addition to bonding, i.e., their primary function, adhesive tape is also used for sealing purposes, by protecting bonded components against penetration by an external medium [1], [4], and [5]. Manufacturers of industrial pressure-sensitive adhesive tapes will sometimes develop their products tailored to specific assembly and industry needs [6] to [8].

The term "pressure-sensitive" describes adhesives that are aggressively and permanently tacky in the dry form at room temperature and firmly adhere to a variety adherends' surfaces upon mere contact, without the need of more than hand pressure [9]. Pressure-sensitive adhesives consist mainly of tacky polymeric materials that adhere to adherends surface upon applying a contact pressure [9] to [11]. Pressure-sensitive adhesives require a balance of cohesive strength and viscoelastic properties. Such adhesives can be easily detached from the adherend surface and may be reusable [12]. An essential property of pressure-sensitive adhesive tapes is their tack performance, which relates the adhesive force generated by a small short-term pressure on the tapes [12]. One of the important features of pressure-sensitive adhesive tapes is their flexibility (even exceptional flexibility), which allows for relative component movement in the assembly related to the thermal expansion of adherends [4], [5], [13], and [14].

Various issues of mechanical properties related to pressure-sensitive adhesives are presented in many works [7], [11], [12], and [15] to [17]. Czech and Milker [7] underlined that pressure-sensitive adhesives (PSA) presented a novel generation of self-adhesives with a large number of excellent properties. In this work, several groups of pressure-sensitive adhesives were described. Foster et al. [15] defined bonding principles for the development of commercial water-bone pressure-sensitive adhesive. Zosel [17] presented that the correlations between shear resistance and the mechanical properties of pressure-sensitive adhesives. Also, issues related to the rheological properties of pressure-sensitive

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adhesive on the mechanical behaviour were discussed, among others in the works [10], [16], and [18] to [20]. Dynamic mechanical properties of pressure-sensitive adhesives were presented by Chu [10]. Marin and Derail [20] investigated the relationship between rheological and peeling properties for hot-melt pressure-sensitive adhesives based on homopolymers or copolymers blended with tackifier resins. Sun et al. [21] indicated that the mechanical properties of pressure-sensitive adhesives are usually described by tack, shear resistance and peel strength. Sosson et al. [22] investigated the shear failure mechanisms of pressure-sensitive adhesive. The effect of tackifier on the adhesive properties of pressure-sensitive adhesives tape was investigated by Sasaki et al. [23].

The article characterizes adhesive joints formed using industrial pressure-sensitive adhesive tapes that were subjected to temperature shock testing. The major finding emerging from the tests was the positive effect of thermal shocks on the mechanical strength of pressure-sensitive adhesive tape bonded joints.

1 METHODS AND EXPERIMENTAL

1.1 Adherends and Pressure-Sensitive Adhesives

The substrates bonded using the tested adhesive tapes were: C45 steel sheets (PN/EN 10083-2), EN-AW 5754 aluminium alloy sheets (PN-EN 573-3) and Grade 2 titanium sheets (according to American standard ASTM F67:2000-Ti Grade 2). The thickness of the adherends was 1 ± 0.02 mm.

Two pressure-sensitive adhesives in the form of double-sided tapes were subjected to testing: 3M VHB double-sided tape (3M company, VHB brand, No. 4947F, 3M Deutschland GmbH) and 3M Scotch® double-sided pressure-sensitive adhesive tape (3M company, Scotch® Brand, 3M Deutschland GmbH). Table 1 lists the characteristics of the 3M VHB tape. The presented characteristics have been prepared based on the information provided on the manufacturer's websites [24] to [26].

Table 1. *Characteristics of 3M VHB pressure-sensitive adhesive tape*

Properties	Details/value
Adhesive tape specification	Double-sided adhesive tape
Adhesive type	Multi-purpose acrylic
Foam type	Acrylic foam
Density	720 kg/m³
Liner	PE film

The maximum and minimum operating temperatures are +90 °C and –40 °C. Short- and long-term temperature resistance are 149 °C and 93 °C, respectively.

Selected properties of the 3M Scotch® double-sided pressure-sensitive adhesive tape are shown in Table 2. The maximum and minimum operating temperatures are +93 °C and -35 °C.

Table 2. *Characteristics of 3M Scotch® pressure-sensitive adhesive tape*

Properties	Details/value
Adhesive tape specification	Double-sided adhesive tape
Adhesive type	Modified acrylic
Liner	PET

1.2 Adhesive Joints and Adhesives Samples

Two research objects were used in the study: single-lap adhesive joints of three construction materials, i.e., structural steel sheet (C45), aluminium alloy sheet (EN-AW 5754) and titanium sheet (Grade 2), joined with pressure-sensitive adhesives, and a pressure-sensitive adhesive in the form of rectangular samples.

The single-lap adhesive joints (Fig. 1) have the following dimensions: sheet width (*ws*) 20±0.12 mm, sheet length (*Ls*) 100±0.32 mm, overlap length after curing process (*lad*) 20±0.58 mm, sheet thickness *g* = 1±0.02 mm, adhesive tape thickness (*tad*): 3M VHB pressure-sensitive adhesive tape 1.1 mm, 3M Scotch® 1.9 mm.

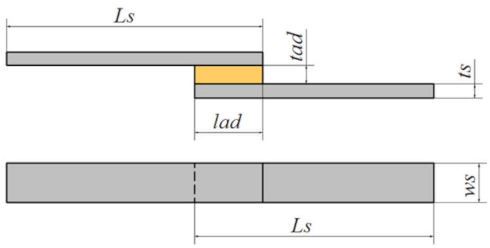

Fig. 1. *The parametric scheme of single-lap adhesive joints*

For each type of adherends and pressure-sensitive adhesives, 8 adhesive joints were made. A total of 96 adhesive joint samples were subjected to strength tests (3 types of adherends × 2 types of pressure-sensitive adhesives, tapes × 2 variants of testing conditions × 8 samples).

The dimensions of rectangular samples of pressure-sensitive adhesives are 100 mm × 20 mm. For each pressure-sensitive adhesive variant, 6 adhesive samples were made.

1.3 Bonding Technology

The adhesive joints were prepared in several steps: adherend surface preparation, cutting off the pressure-sensitive adhesive tape, applying the adhesive onto adherends surfaces, and curing.

1.3.1 Surface Treatment and Applying the Adhesive

The surface treatment of adherends prior to bonding consisted of degreasing with acetone. Specifically, the degreasing agent was applied in 3 repetitions onto the surfaces: after the first two applications, it was wiped off with dust-free swabs; after the third application, the samples were allowed to dry for approx. 2 minutes. The surface treatment procedure was performed at 26 ± 1 °C and humidity 40 ± 1 %.

The pressure-sensitive adhesive tape was cut with scissors to the required overlap length of 20 mm. Next, it was applied onto one of the adherend surfaces and pressed appropriately once the adherend and the adhesive tape were in line. Given that the bond strength is relative to the condition and the size of the contact surface (according to theoretical mechanics), an even amount of pressure needed to be applied. To ensure better contact between the tape and the bonded surface, and thus to increase the strength of the fixture, the proper pressure was applied with a hand roller.

1.3.2 Curing

Once the joint was assembled, it was subjected to curing, according to the following procedure:

- 2-hour subjecting under a load of 0.20 MPa, at a temperature of 26 ± 1 °C and humidity of 41 ± 1 %,
- hold at a temperature of 150 ± 1 °C for 10 minutes (Fig. 2),
- cooling at 26 ± 1 °C for 1 hour.

During curing, the joints were heat-treated at an elevated temperature to accelerate and improve the deposition of the tape adhesive in the irregularities of the adherends. The curing was carried out in a climatic chamber SH-661 (Klimatest, Poland).

The bonded joints were subsequently conditioned at 23 ± 1 °C and relative humidity of 28 ± 1 % for 24 hours, upon which time their quality was verified in visual inspection. Finally, the specimens were divided into two test batches that differed in terms of the thermal post-treatment.

1.3.3 Thermal Post-Conditioning

Prior to failure strength tests, the specimens from the first test group (RT) conditioning in room temperature, whereas for the second variant (TS) the specimens were additionally subjecting using thermal shocks, carried out using a thermal shock chamber STE 11 (ESPEC, Klimatest, Poland). The test groups are described in Tables 3 and 4.

Table 3. *Description of test groups*

Test group variant	RT (without thermal shocks)	TS (with thermal shocks)
Conditions	Temperature: 23 ± 1 °C RH: 28 ± 1 % Time: 24 h	500 cycles 1 cycle: +60 °C / 15 min. and −40 °C / 15 min.

Table 4. *Description of test adhesive joints*

Adherend (designation)	Adhesive tape 3M	Test group	Designation of adhesive joints
Steel (S)	VHB	RT	S/VHB/RT
	Scotch®		S/S/RT
	VHB	TS	S/VHB/TS
	Scotch®		S/S/TS
Aluminium alloy (Al)	VHB	RT	Al/VHB/RT
	Scotch®		Al/S/RT
	VHB	TS	Al/VHB/TS
	Scotch®		Al/S/TS
Titanium (Ti)	VHB	RT	Ti/VHB/RT
	Scotch®		Ti/S/RT

1.4 Strength Test

The shear strength tests of adhesive joints were conducted according to the DIN EN 1465 standard test temperature 23 ± 1 °C and during the test speed of 50 mm/min, using Zwick/Roell Z2.5 testing machine (Zwick/Roell GmbH&Co. KG, Ulm, Germany).

The elongation strength tests pressure-sensitive adhesive samples were performed at test temperature 23 ± 1 °C and during the test speed, according to DIN EN ISO 527-1 standard, using Zwick/Roell Z2.5 testing machine (Zwick/Roell GmbH&Co. KG, Ulm, Germany).

2 RESULTS

2.1 Mechanical Properties of Adhesive Joints - RT Variant: Conditioning in Room Temperature

Figs. 2 and 3 compare the results from shear strength tests of steel sheet, aluminium alloy sheet and titanium sheet adhesive joints bonded using two pressure-sensitive adhesive tapes. Specifically, Fig. 2 reports the strength performance of these joints, and Fig. 3 compares the elongation at break of joints under testing conditions. The designations in the charts in Figs. 2 and 3 have been adopted in accordance with the designations presented in Table 5.

From the data presented in Fig. 2, it can be seen that adhesive joints bonded with the acrylic adhesive tape tended to develop higher strength, regardless of the adherends. With respect to the material of adherends, the aluminium alloy was shown to develop the highest shear strength of all the joints, both when bonded with the 3M VHB (0.38 MPa) and the 3M Scotch® (0.28 MPa) pressure-sensitive adhesive tapes. For these types of joints, the difference in the shear strength amounted to approx. 27 %. The lowest shear strength was recorded for the adhesive joints of titanium sheets. This applies to both types of pressure-sensitive adhesive tapes: 3M VHB (0.35 MPa) and 3M Scotch® (0.15 MPa). The shear strength of titanium adhesive joints joined with 3M Scotch® pressure-sensitive adhesive tape corresponded to approx. 40 % of the shear strength of adhesive joints made with 3M VHB pressure-sensitive adhesive tape.

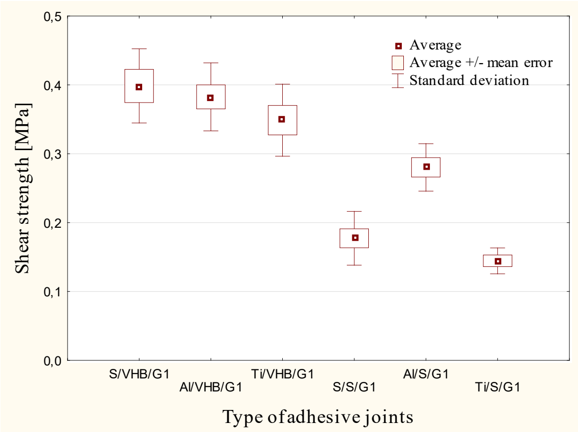

Fig. 2. *Shear strength of tested adhesive joints - RT variant*

A meaningful difference in shear strength was also observed in the case of steel sheet joints. The strength of joints made with the 3M VHB pressure-sensitive adhesive tape is 0.35 MPa and 0.18 MPa with the use of 3M Scotch® pressure-sensitive adhesive tape, which corresponds to almost 50 % of the difference between the strength of the compared adhesive joints. In general, in all material cases, greater strength was observed when using 3M VHB pressure-sensitive adhesive tape.

As indicated in the previous paragraph, significantly greater differences in the strength values were observed in the joints bonded with 3M Scotch® pressure-sensitive adhesive tape (nearly 50 %), which can be interpreted as the effect of this type of tape sensitivity to the type of adherend used in the bonding processes. Similar dependencies result from the analysis of the elongation of adhesive joints (Fig. 3).

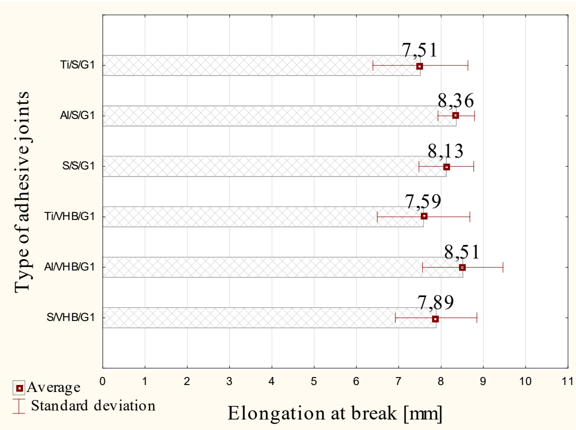

Fig. 3. *Elongation at break of tested adhesive joint – RT variant*

Considering the elongation values (Fig. 3), it can be seen that there are no statistical differences of elongation between the different tapes (3M VHB and 3M Scotch® pressure-sensitive adhesive tapes) for the same material due to the relatively high standard deviations. Considering all variants of the samples of adhesive joints depending on the base material, it can be seen that the highest elongation was obtained in aluminium alloys adhesive joints, and the lowest in titanium adhesive joints. Moreover, for the pressure-sensitive adhesive tapes used, the difference between the highest and lowest average elongation is similar and amounts to approximately 10 %; however, it has also been shown that the type of adherends affects the properties of the joints (including the elongation) in strength tests.

2.2 Mechanical PROPERTIES of Adhesive Joints - RT Variant: Conditioning in Room Temperature

The results obtained from the shear strength tests conducted on adhesive joints of steel and aluminium alloy sheet substrates that were bonded with the two types of pressure-sensitive adhesive tapes are reported in Figs. 4 and 5.

Several observations emerge from the comparative analysis of the performance (shear strength and elongation at break) of pressure-sensitive adhesive tape joints subjected to 500 thermal shock cycles (Figs. 4 and 5):

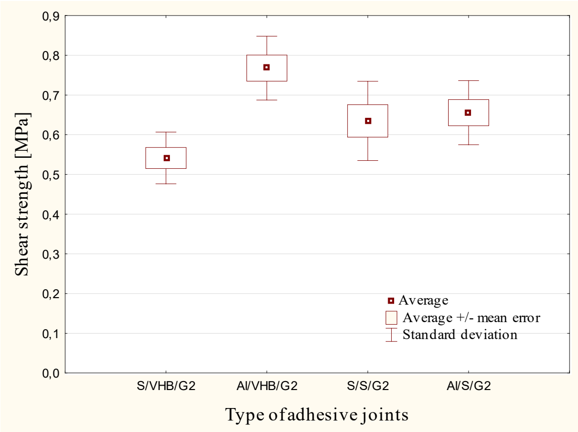

Fig. 4. *Shear strength of tested adhesive joints - TS variant*

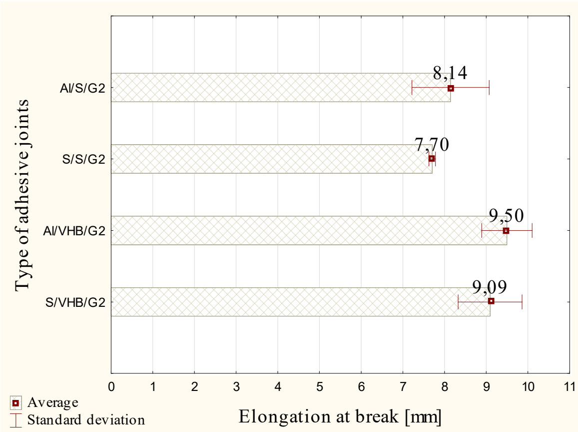

Fig. 5. *Elongation at break of tested adhesive joint – TS variant*

- the strength parameters of adhesive joints of aluminium alloy determined in tests were higher compared to the steel adhesive joints, which applies to both types of pressure-sensitive adhesive tapes,
- the aluminium alloy adhesive joints bonded with the 3M VHB pressure-sensitive adhesive tape were stronger than the steel adhesive joints by 27 % on average,
- the difference in joint strength was less significant in the case of the 3M Scotch® pressure-sensitive adhesive tape, amounting to 3 % on average,
- when comparing the elongation of specimens bonded using the 3M VHB pressure-sensitive adhesive tape, the difference between the adherends was equal to 4 %, while for the 3M Scotch® pressure-sensitive adhesive tape it was 11 % on average.

The bonded joints of titanium sheets exhibited the lowest strength, regardless of the type of adhesive type used and were therefore excluded from thermal shock testing.

2.3 Mechanical Properties of Adhesives

The results of strength parameters pressure-sensitive adhesive tapes shown that the average value of the tensile strength of the 3M VHB pressure-sensitive adhesive tape was 0.43±0.03 MPa, whereas the average value of the tensile strength of 3M Scotch® pressure-sensitive adhesive tape was 0.34±0.06 MPa. The modulus of the 3M VHB pressure-sensitive adhesive tape was 1.30±0.12, and the modulus of the 3M Scotch® pressure-sensitive adhesive tape was 0.23±0.09.

It can be seen that 3M VHB pressure-sensitive adhesive tape is characterized by a 20 % higher value of tensile strength than Scotch pressure-sensitive adhesive tape. In the case of the tensile modulus, it was observed that the 3M Scotch® pressure-sensitive adhesive tapes have almost 5 times lower value compared to the VHB pressure-sensitive adhesive tape. Elongation at break was at a similar level, and no significant differences were observed, i.e., for the 3M VHB pressure-sensitive adhesive tape was 720±43 %, and was 733±30% for the 3M Scotch® pressure-sensitive adhesive tape.

3 DISCUSSION

The comparison of the results of shear strength of adhesive joints curing and conditioning in room temperature (RT) and additionally subjected to thermal shocks (TS) was presented in Figs. 6 and 7.

Based on the results presented in Fig. 6, it can be seen that the strength of steel adhesive joints that were subjected to thermal shocks is higher than those of joints that were conditioned at ambient temperature. However, the extent to which the presence of thermal shocks contributes to improving the strength properties of steel adhesive joints depends on the type of pressure-sensitive adhesive tape in use. The adhesive joints bonded with the 3M VHB pressure-sensitive adhesive tape were observed to develop strength increased by 37 % when thermal shock treatment was applied. The difference was even higher in adhesive joints bonded with the 3M Scotch® pressure-sensitive adhesive tape, in which case the increase in the strength of adhesive joints exceeded 80 %.

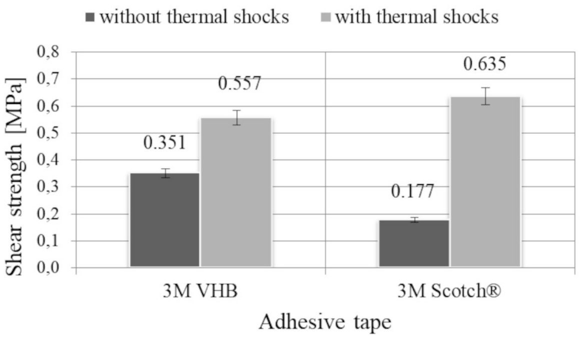

Fig. 6. *The shear strength of steel adhesive joints subjected and not subjected to thermal shock testing*

Considering the correlation between the type of adherend of adhesive joints after thermal shock and the type of pressure-sensitive adhesive tapes, it was observed that the steel adhesive joints prepared with the 3M Scotch® pressure-sensitive adhesive tape showed a 15 % higher strength than the steel adherends bonded with the 3M VHB pressure-sensitive adhesive tape: 0.63 MPa and 0.54 MPa, respectively. In the adhesive joints not subjected to thermal shocks, the opposite mechanism occurred: steel adhesive joints bonded with the 3M VHB pressure-sensitive adhesive tape were capable of resisting higher loads than the 3M Scotch® pressure-sensitive adhesive tape-bonded joints. Also, the difference was far more significant, reaching close to 50 %. What may be then inferred from the observation is that thermal shocks contribute to a certain "levelling-off" of the strength properties of pressure-sensitive adhesive tape, and thus exhibit a positive effect on the strength of adhesive joints.

Considering the shear strength of adhesive joints of aluminium alloy sheets not subjected to and subjected to thermal shock, significant differences in the results of this strength parameter were observed (Fig. 7). Adhesive joints subjected to thermal shocks were characterized by higher shear strength of their joints, and this difference is more than twofold.

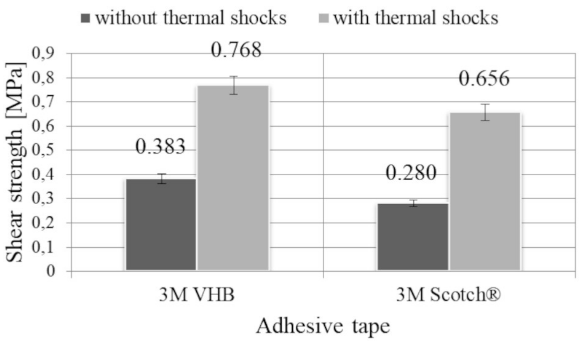

Fig. 7. *The shear strength of the aluminium alloy adhesive joints subjected and not subjected to thermal shock testing*

After the thermal shock, the adhesive joints of aluminium alloy sheets joined with 3M VHB pressure-sensitive adhesive tape (0.77 MPa) are almost 15 % more durable than joints made with 3M Scotch® pressure-sensitive adhesive tape (0.66 MPa). As in the case of bonding steel sheets, there is a clear discrepancy between the strength of adhesive joints prepared with 3M VHB and 3M Scotch® pressure-sensitive adhesive tapes not subjected to thermal shocks: it amounted to approx. 27 %. Therefore, it can be assumed that the heat causes the pressure-sensitive adhesive to cross-link further, as a result of which the properties of the adhesive joints become similar. Nevertheless, other factors were likely to have contributed to this, such as their specific material properties

Thermal shocks are widely known to be among the factors degrading polymer materials, including adhesives. According to the definition of the term, degradation is a process of structural modification that may result from physical or chemical changes occurring within the polymer under the long-term impact of various external factors [4] and [5]. Okba et al. [5] presented that the decrease of residual compressive and tensile strengths depends on the type of polymer adhesive, level of elevated temperature, type of applied stress and, to a lesser degree, on exposure time. The residual bond strength was reduced, and the mode of failure changed due to the high temperature, prolonged exposure time, type of polymer adhesive and the increase in the surface area of the bond. Gilbert et al. [19] investigated the effect of the rheological properties of industrial hot-melt and pressure-sensitive adhesives on the peel behaviour at various temperatures. In the conducted tests, it was noticed that the failure was cohesive with regard to the adhesive layer, and the cracks appeared at the beginning of the adhesive joint overlap. However, as it could be inferred from the results reported here, in certain cases in the first phase of degradation, the properties of an exposed material may actually improve, particularly its mechanical strength. This is a result of additional cross-linking of the material structure that is induced by heat, for example. It is only at a later stage (over a prolonged effect of degradation factors) that other processes begin to contribute, e.g., excessive cross-linking or molecular weight reduction, initiating the deterioration of such material properties, such as strength or elongation, as underlined by Benedek and Feldstein [14] and also Chang [8].

The information from the preceding paragraph and the results from the strength and elongation tests seem to suggest that, in the reported cases, the mechanical strength of adhesive joints bonded with specific pressure-sensitive adhesive tapes was increased by subjecting the specimens to 500 thermal shock cycles, carried out at +60 °C and –40 °C. It should be noted that the applied temperatures did not exceed the values recommended by the manufacturer regarding their maximum (+90 °C for VHB pressure-sensitive adhesive tape and +93 °C for 3M Scotch® pressure-sensitive adhesive tape) or minimum operating temperatures (–40°C for VHB pressure-sensitive adhesive tape and –35°C for 3M Scotch® pressure-sensitive adhesive tape, although in the last pressure-sensitive adhesive tape the minimum temperature was slightly exceeded). However, it is probable that a greater number of cycles, i.e., increased duration of thermal shocks, could lead to a reduction in the strength of the joints under consideration due to, for instance, excessive cross-linking of the adhesive or molecular weight reduction.

The results of elongation of the adhesive joint specimens bonded with the pressure-sensitive adhesive tapes under investigation that were or were not subjected to thermal shocks are presented in Fig. 8 (steel adhesive joints) and in Fig. 9 (aluminium alloy adhesive joints).

Several observations can be drawn from the elongation tests carried out on the steel adhesive joints subjected and not subjected to thermal shocks (Fig. 8):

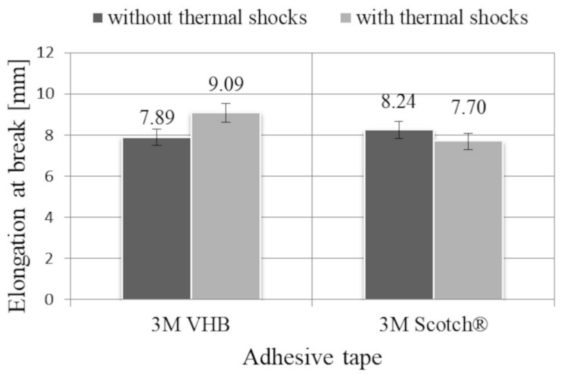

Fig. 8. *Elongation at break of steel adhesive joints with and without thermal shock*

- thermal shocking improved the elongation at break of adhesive joints bonded with the 3M VHB pressure-sensitive adhesive tape (9.09 mm). The difference between the elongation at break of adhesive joints prior to an after thermal shocks is 13 %;
- adhesive joints bonded with the 3M Scotch® pressure-sensitive adhesive tape did not respond positively to thermal shocks: slightly better elongation properties were exhibited by the non-post treated joints (8.24 mm versus 7.70 mm), and this difference was approx. 6 %;
- following the series of thermal shocks, adhesive joints bonded with the 3M VHS pressure-sensitive adhesive tape showed a 15 % higher elongation at break value than the 3M Scotch® pressure-sensitive adhesive tape-bonded specimens.

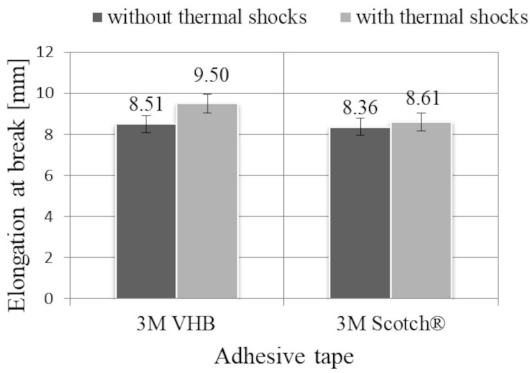

Fig. 9. *Elongation at break of the aluminium alloy adhesive joints with and without thermal shock*

Considering the results from the elongation tests presented in Fig. 9, it can be seen that:

- with respect to the type of pressure-sensitive adhesive tape bonding the aluminium alloy adherends, higher elongation at break was obtained after subjecting the adhesive joints specimens to a specific cycle of thermal shocks;
- after thermal shocks, adhesive joints bonded with the 3M VHS pressure-sensitive adhesive tape showed higher elongation at break value (by about 10 %) compared with the 3M Scotch® tape – similarly to the steel sheet joints;
- the difference in the elongation at break of the adhesive joints of the aluminium alloy adherends bonded with the 3M VHB pressure-sensitive adhesive tape subjected and not subjected to thermal shocks is 10 %, while in the same adherends adhesive joints joined with the 3M Scotch® pressure-sensitive adhesive tape, the difference is negligible – approx. 2 %.

The results above (Figs. 8 and 9) confirm that, with the exception of a single case, the applied number and type of thermal shock cycles increase the elongation at break of adhesive joints prepared with the tested pressure-sensitive adhesive tapes.

Sun et al. [21] underlined that the adhesion properties of pressure-sensitive adhesives strongly depend on surface roughness, tackifier compatibility, monomers, cross-linking degree and others. On the basis of the obtained results, it can be observed that the type of adherends play an important role in the mechanical properties of adhesive joints prepared by pressure-sensitive adhesives. By bonding thicker (stiffer) elements, a greater strength of the joints is obtained but lower maximum stress of the joined materials under failure load. This was also confirmed in the work of Sun et al. [21] and in the work of Peykova et al. [27], who also indicated that different surface also affects the cavity growth mechanisms.

According to Dimas et al. [28], several factors determine the mechanical properties of pressure-sensitive adhesive, e.g., the type of adhesive. Although both acrylate-based pressure-sensitive adhesives were used in the study, the type of acrylic was probably different (the information is very general from the manufacturer on this subject); the thickness and the different base were different. That is, the factors mentioned by Dimas et al. [28] could have influenced the noticeable differences in the strength of the adhesive joints of the materials joined with the use of both tapes. According to Chu [10] the performance of PSA is related to the viscoelastic response of the bulk adhesives as well as to the surface energies of the adhesives and adherend. Differences in the strength of adhesive joints made with two different pressure-sensitive adhesives (Fig. 2) can probably be explained by the different structures of the adhesive layer and its thickness. The results presented by Poh and Kwo [29] highlighted the importance of the thickness of the adhesive layer on the adhesive substrate. They presented that, generally, peel and shear strength increase with coating thickness. The type of materials forming the pressure-sensitive adhesive is an equally important factor, which was emphasized in the works of, among others, Rodrigez et al. [18], Chang [8], and Marin and Derail [20].

4 CONCLUSIONS

The experimental data suggest that in the investigated range of thermal shocks (the number of cycles, temperature and duration of positive and negative temperatures), commonly regarded as a degradation factor, the post-conditioning does not appear to trigger the deterioration of the mechanical properties of adhesive joints bonded with pressure-sensitive adhesive tapes; nevertheless, the increase in strength is also associated with the type of adherend. Thus, there is a positive correlation between thermal shocks and the mechanical strength of adhesive joint bonded with pressure-sensitive adhesive tapes, which should be linked primarily with additional cross-linking of the adhesive material structure under exposure to heat, and the resulting increase in the mechanical strength of the adhesive joints. An implication of this is that pressure-sensitive adhesive tapes exhibit a good capacity for bonding the considered adherends under the considered operating conditions.

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