TEMPERATURE INFLUENCE ON THE CHANGE OF THE SANDWICH MATERIAL ADHESIVE PROPERTIES

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The automotive manufacturing represents one of the most developing segments of the engineering industry. The persisting tendency of designers to achieve the best technological level, car´s safety level and also ecological running at keeping the low price level means necessity to still implement into own production new types of materials. Among these materials also belong so-called sandwich materials which combine steel sheets with the plastic core. These materials are used in the car design due to their lower weight and excellent acoustic properties. As a disadvantage of such materials there is lower temperature stability and worse technological processability. This paper deals with the evaluation temperature influence on the change of the sandwich material mechanical properties. For tests there were selected the characteristic mechanical tests for different loading types in light of the adhesive properties testing – the lap shear test and the T-peel test. The range of the testing temperature was from -40°C up to 80°C and was chosen with respect to the commonly used criterions for temperature resistivity of parts designed for the car-body design.

KEYWORDS

sandwich material, car-body design, material tests, temperature resistance, shear resistance

1 INTRODUCTION

Sandwich materials represent a group of materials designed for the lightweight applications. Sometimes these materials are termed as sandwich-structured composites [Gay 2015]. There is a lot of different types of sandwich materials which differ in light of used materials. For a skin material is mostly used glass or carbon-fiber reinforced plastics or metal sheets. There are also a lot of core materials like e.g. polyurethane or metal foams. These days it is also very widely used a honeycomb for a core structure [Vinson 2005]. In this paper was tested sandwich material marked as light-core which consists of metal sheets (deep-drawing materials) as skin material and a plastic core. To be more specific - acc. to DSC analysis this core was from polybutylacrylate 723 and sulfoethyl methacrylate.

The aim of this paper was to carry out mechanical tests for this tested sandwich material in light of its adhesive properties in dependence on the temperature. The most typical tests for this approach are termed as T-peel test and the lap shear test [Filipe Martins da Silva 2012]. The T-peel test has quite a special evaluation [Kawashita 2005]. On the other hand it measures a very important quantity termed as the peel strength. The lap shear test is directly focused on the adhesive´s (in this case core) shear properties. Measured results from both tests can provide very important characteristics about the possible applications of this sandwich material [Brockmann 2009].

2 METHODOLOGICAL BASES AND EXPERIMENTAL PART

The whole experimental part of this paper was about testing the sandwich material in light of its adhesive properties. Thus in this paper was lightweight core taken just as adhesive layer between two metal sheets. That is quite special approach, but on the other hand such results can offer very interesting values.

That is why in the experimental part are described and carried out two basic tests of adhesive bonding: T-peel test and lap shear test. In the next chapter is described samples geometry.

2.1 Geometry of the testing samples

Geometry of the testing samples was chosen acc. to standards ISO 11 339 for the T-peel test and ISO 4587 for the lap shear test. Both of these samples are shown in fig. 1 and fig. 2.

T-peel test: the most important input value for this test is right the width of the sample (here w = 25 mm). As a major result of this test it is taken the so-called peel strength PS ($N \cdot mm^{-1}$). Evaluation and all other important computations for this test are summarized in the chapter 3.1.

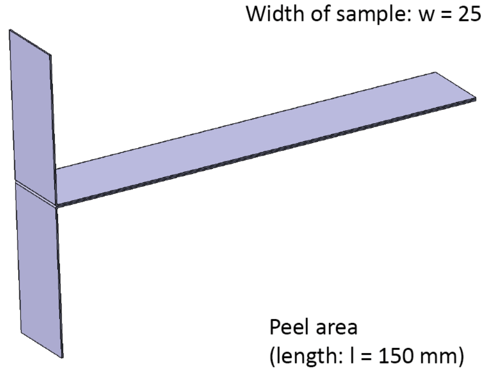

Figure 1. Geometry of the sample for the T-peel test

Lap shear test: such test is directly focused on the lap shear strength τ_{LP} (MPa) between the layers that is computed from equation (1). Evaluation and all other important computations for this test are summarized in the chapter 4.1.

$$\tau_{LS} = \frac{F_{MAX}}{l \cdot w} \tag{1}$$

where:	τ_{LS}	- lap shear strength	(MPa),
	F_{MAX}	- maximal force	(N),
	l	- overlap length	(mm),
	w	- width of sample	(mm).

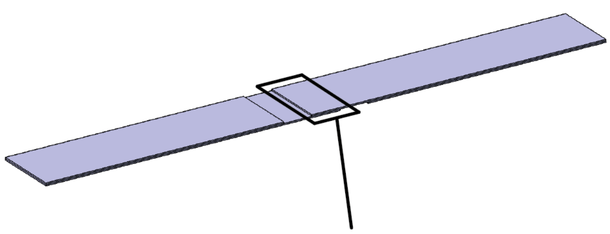

Figure 2. Geometry of the sample for the lap shear test

3 T-PEEL TEST

The T-peel test was made on the testing device TiraTEST 2300. As testing temperatures there were chosen -40 °C, room temperature (RT) and 80 °C. To achieve these temperatures was necessary to use the temperature chamber and holding time for sample was 10 min. As a loading rate v_L was according to standard ISO 11 339 chosen 10 mm·min^{-1}. The whole arrangement of the T-peel test is then shown in fig. 3.

Figure 3. The T-peel test – arrangement of the experiment

3.1 Evaluation of the T-peel test

As was already mentioned before, evaluation of the T-peel test is summarized in the standard ISO 11 339. The major quantity from this test is termed as the peel strength PS (N·mm^{-1}). Note its unit- it is a force per distance and not force per area.

In fig. 4 is shown peeling force F (N) vs. peel distance d (mm) for sample no. 1 at the room temperature (RT). Firstly there can be quite easily evaluated maximal force F_{MAX} (N). However, this force is not so interesting for the T-peel test. Much more important force is termed as average peeling force F_{APF} (N) and is computed from the "stable" area. It means to crop the first and the last 20% of the peel distance (50 mm in this case) and the "stable" area is remaining 60% for the peel length.

There are two major approaches to compute the peel strength PS (N·mm^{-1}). The first method uses just values of the actual peeling force F (N) in the "stable" area which are divided by the width of the sample w (mm) – see equation (2). The second approach firstly computes the average peeling force F_{APF} (N) from the values of actual peeling force F (N) – just by the statistical evaluation. Finally it computes PS (N·mm^{-1}) as F_{APF} (N) divided by width of the sample – see equation (3). Both these procedures are illustrated in fig. 5 and fig. 6 and from both of them can be easily derived unit for PS as (N·mm^{-1}).

$$PS = \frac{F}{w} \tag{2}$$

$$PS = \frac{F_{APF}}{w} \tag{3}$$

where:	PS	- peel strength	(N·mm^{-1}),
	F	- actual peeling force	(N),
	F_{APF}	- average peeling force	(N),
	w	- width of sample	(mm).

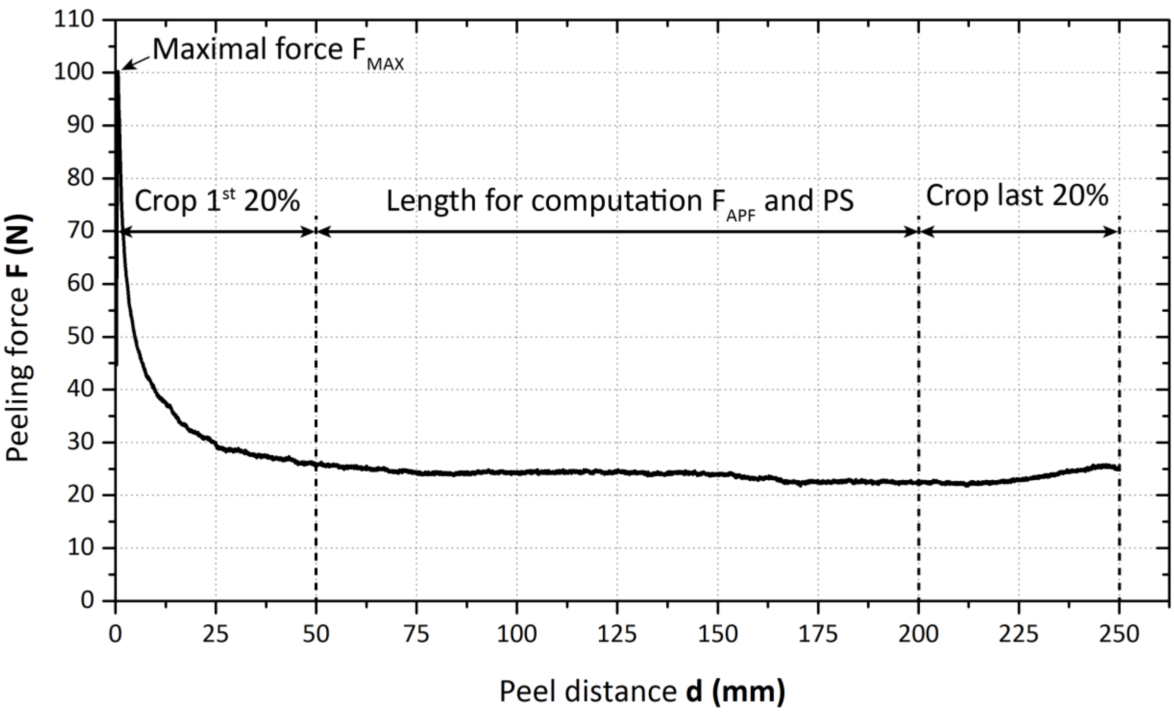

Figure 4. Geometry of sample for the T-peel test

Fig. 5 illustrates computation of the peel strength PS (N·mm^{-1}) directly from its actual values – see equation (2).

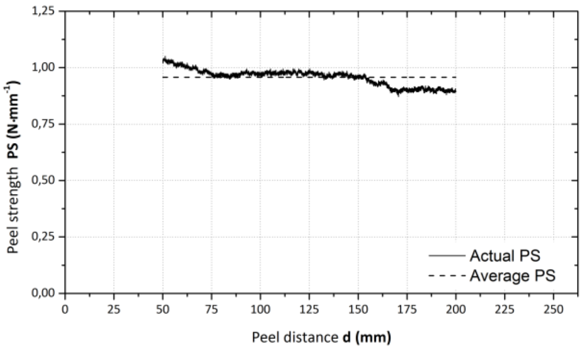

Figure 5. Computation of the peel strength PS (N·mm^{-1}) – 1st approach

In fig. 6 is shown peeling force F (N) vs. peel distance d (mm) for sample no. 1 at room temperature (RT). The average peeling force F_{APF} (N) is an arithmetic mean from the "stable" area.

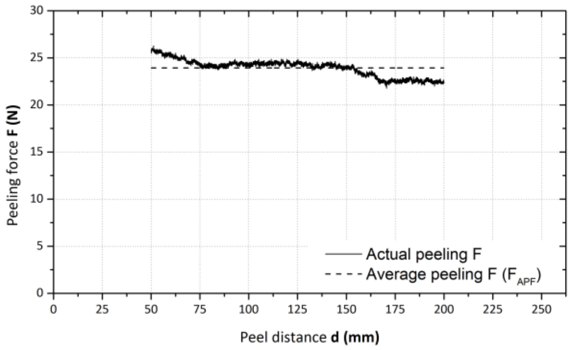

Figure 6. Computation of the peel strength PS (N·mm^{-1}) – 2nd approach

3.2 *Results of the T-peel test*

T-peel test represents one the most important mechanical test which can be carried out in the branch of the adhesive bonding. In this case was used the sandwich material to be tested in light of the adhesive-adherents properties.

As a variable parameter it was chosen testing temperature as following: -40 °C, room temperature (RT) and 80 °C. Testing samples were tested under the required common loading rate, thus v_L = 10 mm·min^{-1}. Width of sample was w = 25 mm. From courses of peeling force F (N) vs. peel distance d (mm) there was computed peel strength PS (N·mm^{-1}). For every testing temperature were measured 5 samples followed by the common statistical evaluation to obtain the arithmetic mean x and the standard deviation s. All major results (F_{MAX}, F_{APF} and PS) in dependence on the testing temperature T (°C) are summarized in table 1 and fig. 7.

From results (see table 1 and fig. 7) it is obvious that the testing temperature has a very strong influence on the PS. It is valid that the lower temperature, the higher PS. Properties of the lightweight core (the plastic one – see chapter 1) changed strongly in dependence on temperature. It seems that it results from the transition temperature of the lightweight core.

Table 1. Statistical evaluation of the T-peel test

T (°C)	F_{MAX} (N)		F_{APF} (N)		PS (N·mm^{-1})	
	x	s	x	s	x	s
-40°C	234,3	15,9	94,5	3,7	3,79	0,03
RT	106,0	8,6	23,3	0,9	0,93	0,05
80°C	64,3	13,0	13,7	0,7	0,55	0,02

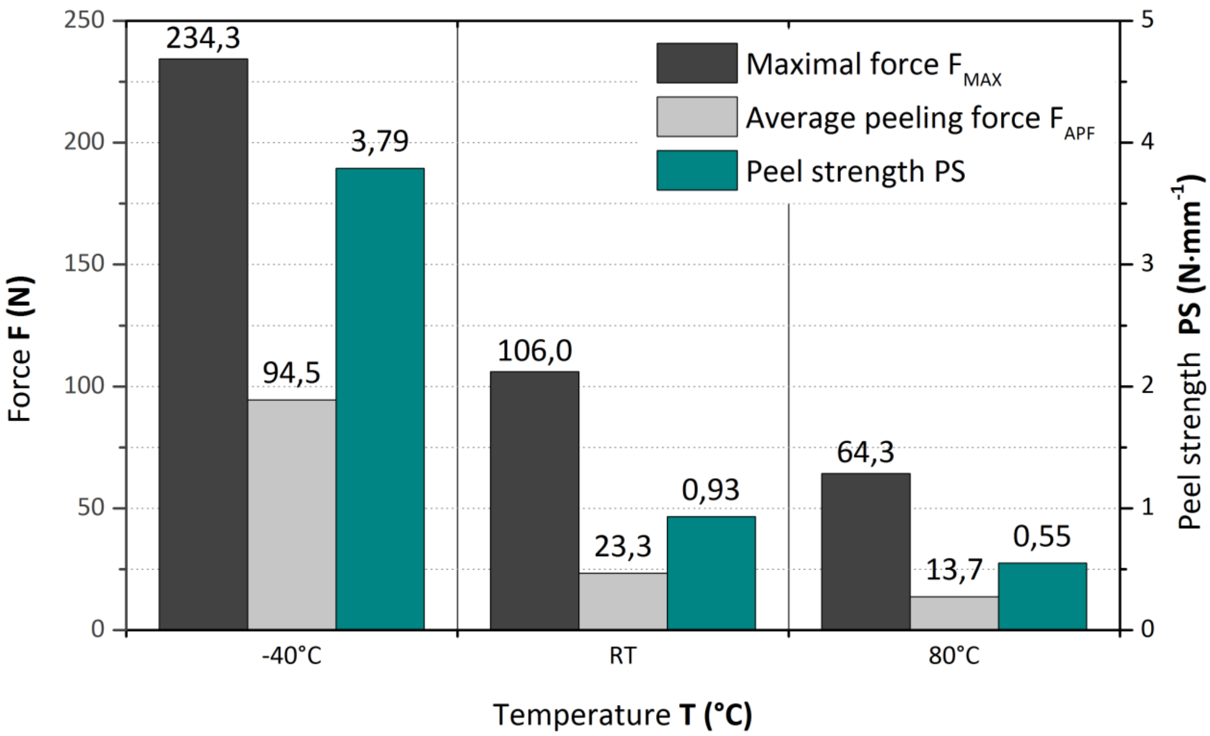

Figure 7. Major results from the T-peel test: F_{MAX}, F_{APF} and PS in dependence on the testing temperature

4 LAP SHEAR TEST

The lap shear test was carried out under the same conditions as in the case of the T-peel test. Thus testing temperatures were again used as -40 °C, room temperature (RT) and 80 °C. The positioning of the testing sample is shown in fig. 8. The loading rate v_L was also 10 mm·min^{-1}. For temperatures -40 °c and 80°C was for cooling and heating of samples used the temperature chamber with holding time 10 min for every sample.

Figure 8. The lap shear test – arrangement of the experiment

4.1 Results of the lap shear test

Graphical result of the lap shear test is shown in fig. 9 where is force F (N) vs. shear distance d (mm) for sample no. 1 at the temperature -40 °C. The most important quantity from this test is given directly by the maximal force F_{MAX} (N). The lap shear strength τ_{LP} (MPa) can be computed from equation (1). All results are statistically summarized in table 2 and fig. 10.

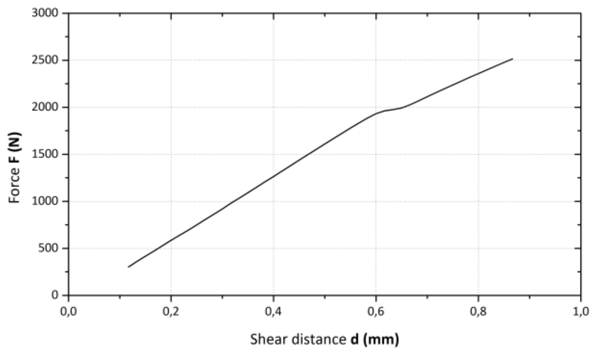

Figure 9. Force F (N) vs. shear distance d (mm) for the lap shear test

Table 2. Statistical evaluation of the lap shear test

T (°C)	F_{MAX} (N)		τ_{LS} (MPa)	
	x	s	x	s
-40°C	2609	107	10,44	0,43
RT	758	30	3,03	0,12
80°C	206	16	0,83	0,06

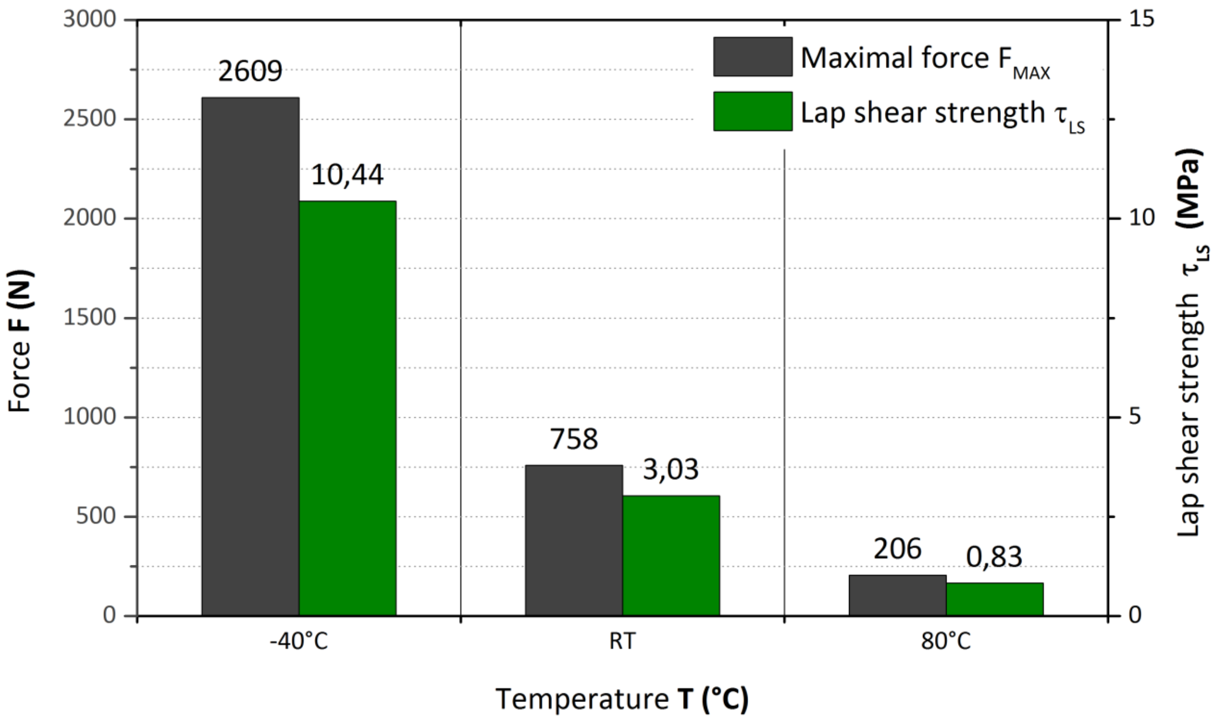

Figure 10. Major results from the lap shear test: F_{MAX} and τ_{LS} in dependence on the testing temperature

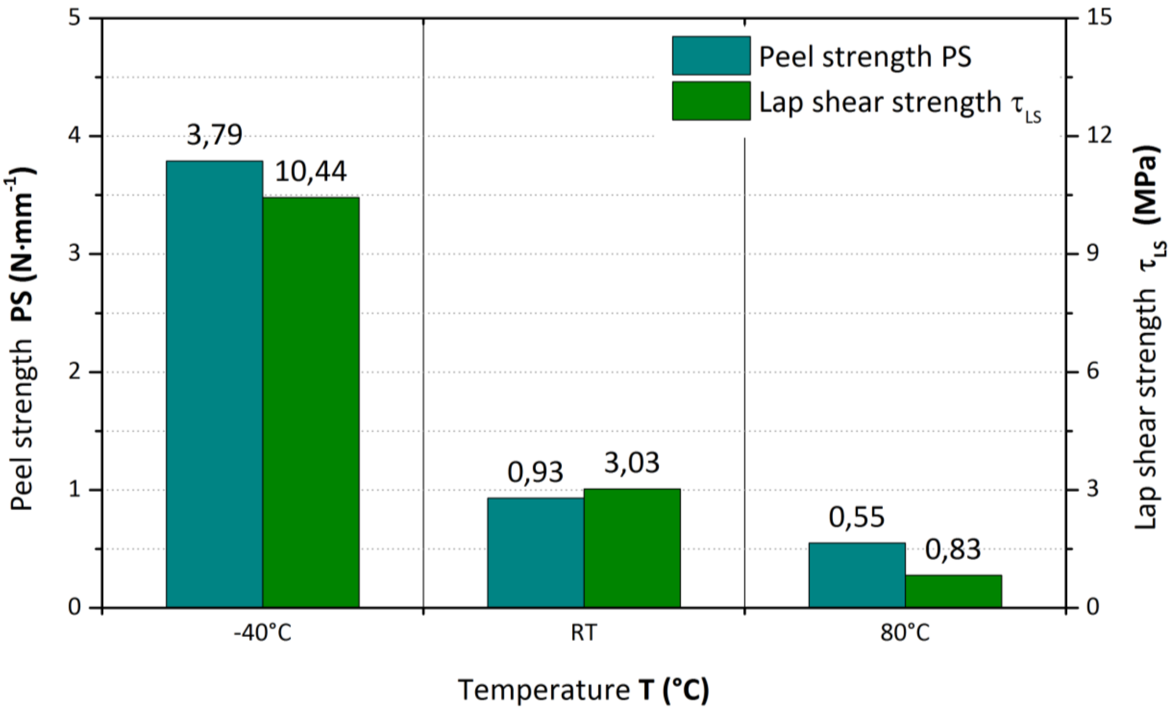

Figure 11. Comparison of the PS and τ_{LS} in dependence on the testing temperature

5 CONCLUSION

This paper describes testing of the sandwich material (metal sheets for the skin and plastic core) in light of the adhesive properties. Thus there were made two basic adhesion tests that are termed as the T-peel test and the lap shear test. That´s quite special approach because these materials are not designed to be loaded in such way. It can be stated that this approach considers the lightweight core as to be an adhesive. However it is also very important for these materials to know their adhesive properties. As a variable parameter there was used the testing temperature (-40 °C, RT and 80 °C).

Results from the both tests revealed the same major tendency. The higher testing temperature, the lower both the peel strength PS ($N{\cdot}mm^{-1}$) and the lap shear strength τ_{LS} (MPa). It is interesting behavior which probably arises from the lightweight core transition temperature. If the values of PS and τ_{LS} for -40 °C are taken as 100%, the decrease upon the temperature is for the peel strength 75.5 % for RT and 85.5 % for 80 °C. For the lap shear strength is this decrease 71 % for RT and 92 % for 80 °C. It is very strong temperature influence and that is why the future research in this branch (sandwich materials and their properties in light of the adhesive properties) should be focused on the core materials with the different transition temperatures. Moreover, there should be tested different values of testing parameters [Dobransky 2015]. The testing temperature influence is obvious and it will worth to measure its wider range. Among another parameters should be tested e.g. the higher loading rate or different lightweight materials of core.

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