Studies Regarding the Performance of Pressure Sensitive Adhesives Based on Carbocatenary Elastomers

II. Shear Strength

IOANA DUSESCU[1], PAUL OCTAVIAN STANESCU[2], CATALIN ZAHARIA[2], GHEORGHE HUBCA[2]

[1] S.C. Haas–C-Impex S.R.L., 1 Ploieşti, Lăpuşna, 100002, Prahova, Romania

[2] Politehnica University of Bucharest, Faculty of Applied Chemistry and Materials Science, Department of Science and Engineering of Polymers, 010072 Bucharest, Romania

The main characteristics of pressure sensitive adhesives are: peel, shear and tensile strength. This paperwork presents the shear tests and related phenomena of pressure sensitive adhesives based on polychloroprene rubber using both metallic and polymeric substrates. The influence of the main parameters which control the shear strength of the adhesive assemblies was studied: nature of the substrates, contact time and pressure.

Keywords: pressure sensitive adhesives, elastomers, polychloroprene rubber

Pressure sensitive adhesives (PSA) adhere to most surfaces with very slight pressure. They are available in solvent and latex or water-based forms. Pressure sensitive adhesives (PSA) are often based on non-crosslinked rubber adhesives (in a latex emulsion or solvent-borne form), acrylic or polyurethane polymers, styrene copolymers (SIS / SBS), and silicones. Pressure sensitive adhesives form viscoelastic bonds that are aggressively and permanently tacky. They adhere with just finger or hand pressure and do not require activation by water, solvent or heat [1-3]. Acrylic adhesives are known for excellent environmental resistance and fast-setting time when compared with other resin systems. Acrylic pressure sensitive adhesives often use an acrylate system. Ethylene ethyl acrylate (EEA) or ethylene methyl acrylate (EMA) copolymers are used to form hot melt PSA adhesives. Natural rubber, synthetic rubber or elastomer sealants and adhesives can be based on a variety of systems such as silicone, polyurethane, chloroprene, butyl, polybutadiene, isoprene or neoprene. Rubber and elastomers are characterized by their high degree of flexibility and elasticity (high reversible elongation). Styrene-isoprene-styrene (SIS) and styrene-butadiene-styrene (SBS) copolymers are commonly applied in pressure sensitive adhesive applications.

The major characteristics which determine the performance of pressure sensitive adhesives are bonding, peel, shear and tensile strength. Bonding is the adhesive ability to rapidly adhere to the substrate and it is a function of wetting [4-6]. Peel strength represents the torque required to separate an adhesive and adherend in the climbing drum peel test. It is a measure of bond strength.

The shear strength of the adhesive assembly implies the cohesive strength of the pressure sensitive adhesive and it is measured as the force per unit area. The shear force is parallel to the plane of adhesive assembly. Many authors proposed definitions for cohesive strength and associated the shear deformation with flow [7-9].

The shear properties involve 2 steps: bonding and debonding. Peel tests need a high loading rate, whereas shear could be measured in static conditions. Literature studies show that the shear strength could be measured as the time of adhesive debonding from the testing panel under a standard stress. According to ASTM D3654 (method A) shear strength is the time of adhesive assembly debonding after 1 h contact time. The surface covered with adhesive has 1 in^2 (~645 mm^2) under 4 lb stress (18 N). Poor shear strengths are obtained at low debonding times ($t<10$ h); moderate shear strengths between 10-100 h and high shear strengths after 100 h [10].

This paperwork presents the study of the main parameters which influence the shear strength of the adhesive assemblies between different substrates with pressure sensitive adhesives based on polychloroprene rubber.

Experimental part

Materials and methods

Parallelepiped samples of aluminium alloy 2024T3, steel (MAIRON Galati S.A.), polymethylmethacrylate (ProSEP S.R.L., Craiova), rigid PVC (Royalite from Spartech Corporation) and cotton fibers - phenolic resin composite (textolite from Isovolta Group SA) were used. They were bonded by lap joint on a 25.4 x 25.4 mm^2 surface. The assembly of the samples for the shear test is presented in figure 1.

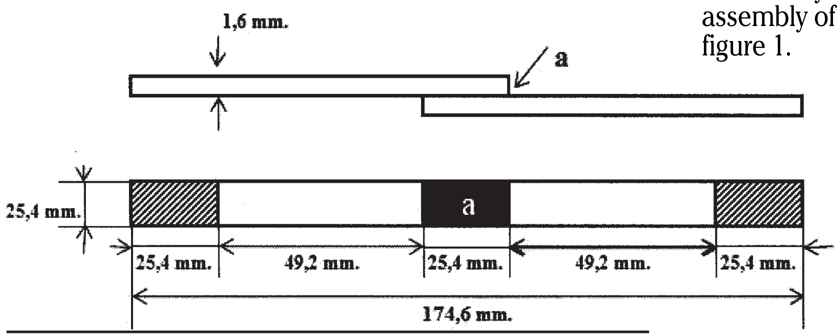

Fig.1. Sample set up for shear test
a. surface covered with adhesive;
b. area within the gripping system

* email: gheorghe_hubca@yahoo.com; Tel.: 0214022703

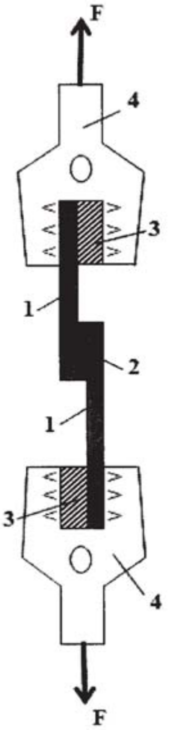

Fig.2. Special device for shear test
1. rigid samples; 2. adhesive layer;
3. device for axial force application;
4. pincher grips

The device for the shear test is presented in figure 2. In this case, only the tangential forces are involved and deformation of the samples as a result of normal forces is avoided. This device allows the axial tensile stress. Measurements were done according to ASTM D 1002-01 and ASTM D 1002-05 on INSTRON 3382 Universal Testing Machine, with a crosshead rate 1.3 mm/min.

Results and discussions

The parameters that influence the shear strength of the adhesive assemblies based on pressure sensitive adhesives with polychloroprene rubber are the following: contact time, pressure and nature of the substrate.

The fracture of the adhesive assembly was monitored by optical means. The optical images were achieved with an Olympus BX41 Microscope equipped with Live view digital SLR camera E-330 (7.5 Mpxl) and special software Quick Photo Micro 2.3.

The influence of the contact time on the shear strength was determined on textolite substrate. The results are shown in figure 3. We may notice the increase of the shear strength with the contact time.

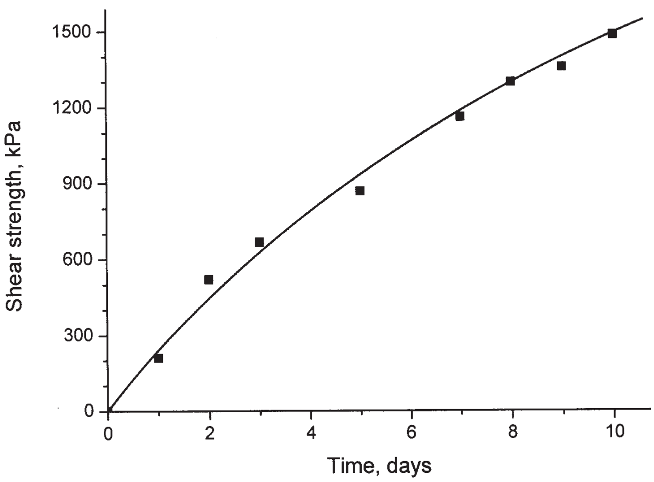

Fig.3. Shear strength versus contact time, using textolite/textolite substrate temperature 25 °C, relative humidity 50 %, contact pressure 20 N/cm², bond surface 25.4x25.4 mm²

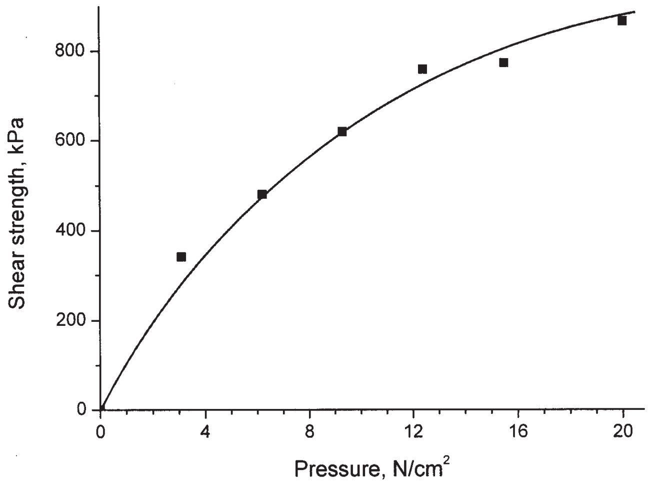

Fig.4. Shear strength versus applied pressure, using PMMA/PMMA substrate temperature 25 °C, relative humidity 50 %, 5 days contact time, bond surface 25.4x25.4 mm²

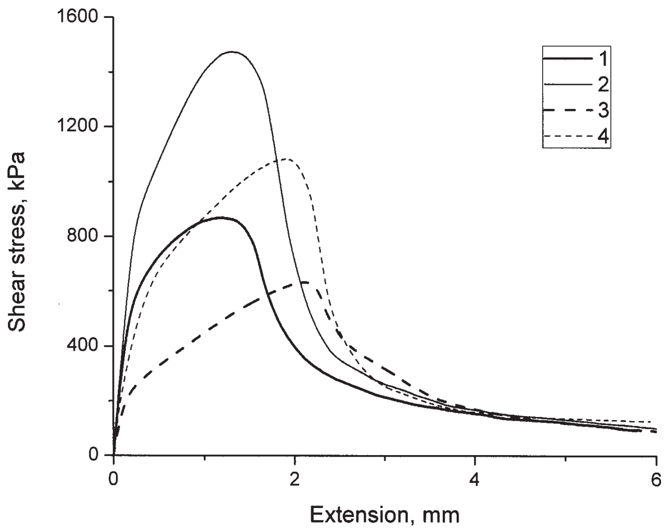

Fig.5. Shear strength versus nature of the substrate
1,2. Textolite/textolite; 3,4. PMMA/PMMA (1,3 after 5 days contact time, 2,4 after 10 days contact time) temperature 25 °C, relative humidity 50 %, bond surface 25.4x25.4 mm², contact pressure 20 N/cm²

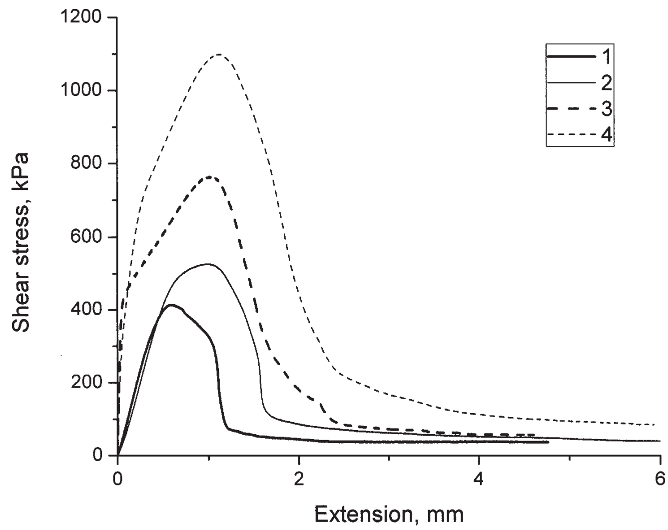

Fig.6. Shear strength versus nature of the substrate
1,2. PVC/PVC; 3,4. Al alloy/Al alloy (1,3 after 5 days contact time; 2,4 after 10 days contact time) temperature 25 °C, relative humidity 50 %, bond surface 25.4x25.4 mm², contact pressure 20 N/cm²

Table 1
DEPENDENCE OF SHEAR STRENGTH AND MECHANICAL WORK OF SEPARATION (W)
ON THE NATURE OF THE SUBSTRATE

No.	Substrate	Shear strength, kPa		w, J/m^2	
		5 days	10 days	5 days	10 days
1	Textolite/textolite	868	1488	2049	3149
2	PMMA/PMMA	620	1085	1823	2634
3	PVC/PVC	419	527	494	883
4	Al alloy / Al alloy	760	1101	1262	2238
5	Steel / Steel	558	744	-	-

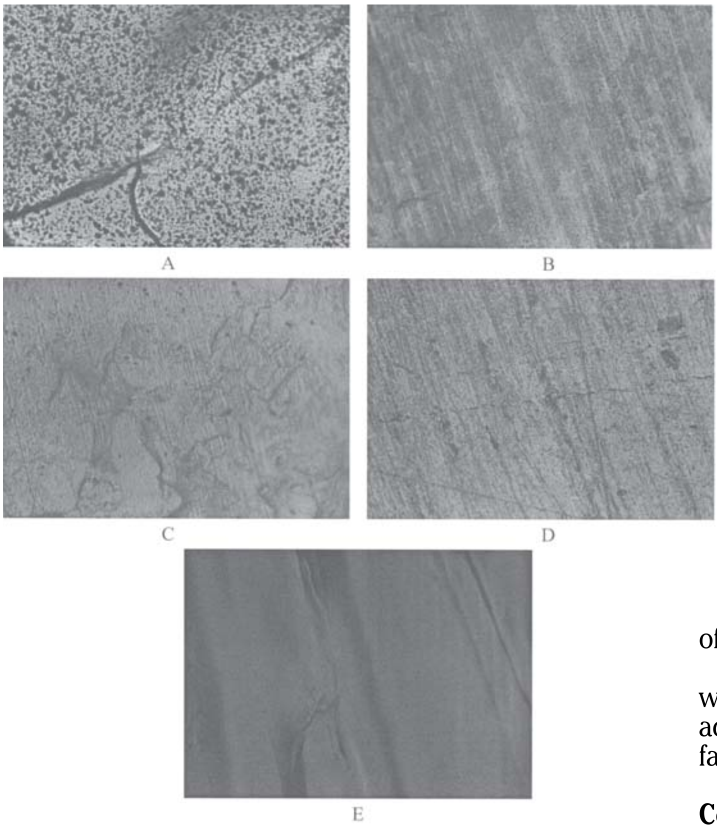

Fig.7. Microphotographs of rupture by shear test A. Al alloy/Al alloy; B. textolite/textolite; C. PMMA/PMMA; D. steel/steel; E. PVC/PVC

The influence of pressure on the shear strength was determined on polymethylmethacrylate substrate after 5 days contact time. The results are presented in figure 4. It is clearly observed the increase of the shear strength with the applied pressure.

The influence of the nature of the substrate on the shear strength was evaluated on the above mentioned substrates: aluminium alloy, rigid PVC, polymethylmethacrylate, textolite and steel.

Figures 5 and 6 show the plot of the shear strength against the nature of the substrate after 5 and 10 days contact time.

Stress-strain curves from figures 5 and 6 are characterized by two parameters: the shear strengths (the maximum values of shear stress) and mechanical work of separation w, defined as the area under the curves to the adhesive covered surface. The mechanical work of separation is the debonding energy (experimentally determined) and it is not the same with thermodynamical adhesion work w_a, calculated from the contact angle and interfacial tension.

The values of the shear strengths and mechanical work of separation are presented in table 1.

After substrates separation, the debonding mechanism was evaluated by optical means. The fracture of the adhesive assembly took place within the adhesive layer, fact revealed by the optical microphotographs (fig. 7).

Conclusions

The research study on pressure sensitive adhesives based on polychoroprene rubber led to the following conclusions:

- shear strength depends on the contact time; the shear strength increases with the contact time, which is in good agreement with diffusion theory of Voyutskii;
- pressure is a major factor, which determines the values of the shear strength; the increase of the applied pressure facilitate the wetting and penetration of the substrate;
- nature of the substrate is one of the most important parameter, which determines the shear strength; the best results are obtained for adhesive assemblies based on textolite and PMMA;
- in most of the cases the fracture of the adhesive assembly took place within the adhesive layer (cohesive fracture).

References

1. SHAOW B. LIN, International Journal of Adhesion and Adhesives, 14, no. 3, 1994, p. 185
2. FRIES, J.A., International Journal of Adhesion and Adhesives, 2, no. 3, 1982, p. 187

3. JENSEN, M.K., BACH, A., HASSAGER, O., SKOV, A.L., International Journal of Adhesion and Adhesives, 29, no. 7, 2009, p. 687
4. RIVLIN, A.S., Paint Technology, no. 9, 1944, p. 215, according to Benedek, I., Pressure-sensitive adhesives and applications, 2 nd Ed., CRC Press, 2004
5. SHERIFF, M., KNIBBS, R.W., and LANGLEY, P.G., J. Appl. Polym. Sci., no. 17, 1973, p. 3423
6. COUNSELL, P.J., and WHITEHOUSE, In: Development in Adhesives, w.c. Wake, Ed., vol.1, Applied Science Publishers, London, 1977, p. 99
7. KÖHLER, H., Adhäsion, 3, 1972, p. 66
8. MERKEL, H., Adhäsion, 5, 1982, p. 23
9. BENDEK, I., FELDSTEIN, M.M., Technology of Pressure-Sensitive Adhesives and Products, CRC-Press, 2008
10. *** Engineering With Pressure-Sensitive Adhesives/Machine Design, http://machinedesign.com/article/engineering-with-pressure-sensitive-adhesives-0420

Manuscript received: 24.11.2010