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

## III. Tensile strength

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*The main characteristics of pressure sensitive adhesives are: peel resistance, shear and tensile strength. This work presents the tensile tests and related phenomena of pressure sensitive adhesives based on polychloroprene rubber with wood and steel substrates. The tensile breaking mechanism for the adhesive assembly is proposed and discussed within this article.*

*Keywords: pressure sensitive adhesives, elastomers, tensile strength, wood, steel*

Pressure-sensitive adhesives pose adhesion and cohesion, required for bonding and de-bonding. The special balance of these properties, the adhesion/cohesion balance, embodies the pressure-sensitive character of the adhesive. Adhesive characteristics are determined by peel and shear strength. The performances of pressure-sensitive adhesives based on polychloroprene rubber (peel and shear strength) were previously reported [1-2].The tacking determined by the separation energy between solvent and adhesive is a measure of the cohesion of the elastomers for the compositions of pressure-sensitive adhesives [3-4]. The adhesion takes place if the adhesive wets the substrate. The literature [5, 6] proved that tacking strongly depends on wetting. A good wetting requires a good fluidity for the adhesive material determined by its viscosity [3, 7-9]. This tacking property could be determined from tensile tests. This test evaluates the stress normally applied to the plane surface of the adhesive pellicle required to break the assembly (de-bonding) [3]. The contact time, contact pressure, rate of separation, temperature and nature of the substrate strongly influence the tensile strength of the adhesive pellicles [11-14].The main aim of this work consists in the study of parameters that influence the tensile strength of adhesive assemblies with pressure sensitive adhesives based on polychloroprene rubber.This research study also focuses on the mechanism of the tensile breaking of these adhesive assemblies according to recent literature data for various types of pressure sensitive adhesives [4-19].

## Experimental part

A pressure sensitive adhesive based on polychloroprene rubber was employed and its composition is shown in table 1.

Tensile tests were performed on spherical specimens made out of oak wood and steel (4 mm and 3.5 mm diameter). The surface of the specimens was polished with a very smooth emery paper (60G), then degreased with methyl-ethyl-ketone and dried. Adhesive was applied in one layer onto both sides of the substrate and left for 30

| No. | Material | Percentage, wt. % | Role in the recipe |
|---|---|---|---|
| 1 | Polychloroprene rubber (Denka A90) | 100 | Elastomer |
| 2 | Hydrogenated colophonium | 10 | Tacking agent |
| 3 | 2,6-di-t-butyl-4-methyl-phenol (BHT IONOL) | 2 | Antioxoidant |
| 4 | MgO | 8 | Active filler |
| 5 | ZnO | 5 | Active filler |
| 6 | Toluen | 375 | Solvent |

- final solution concentration is 20%
- solid content in the final solution is 25%

**Table 1**
COMPOSITION OF ADHESIVE SOLUTION BASED ON POLYCHLOROPRENE RUBBER

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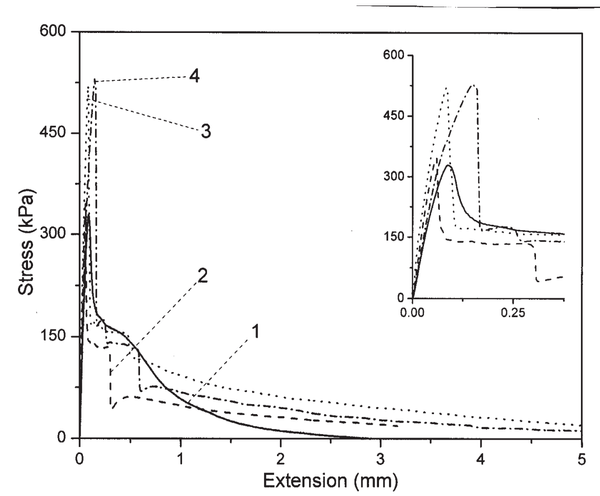


Fig.1. Influence of the contact time on tensile stress
Oak tree wood, temperature 25 °C, relative humidity RH 50 %, bonding surface 12.56 cm$^2$, contact pressure 4 N/cm$^2$, rate of separation 2 mm/min, contact time: 1 – 12 h; 2 – 24 h; 3 – 48 h; 4 – 72 h

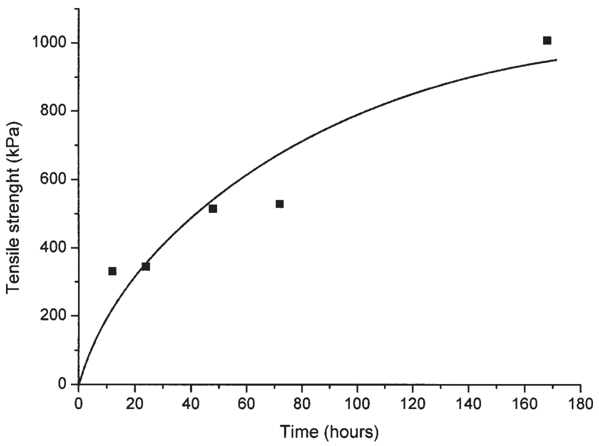


Fig.2. Dependence of the tensile strength on the contact time
Substrate: oak tree wood

min for solvent evaporation. The two specimens were assembled for a constant contact pressure in standard conditions (25 and 50 % relative humidity). Tensile test was done by measuring the stress required to de-bond the two substrates. Measurements were done on INSTRON 3382 Universal Testing Machine with 2 kN loading cell.

The de-bonding force was employed with respect to the adhesive surface of 12.56 cm$^2$ for wood specimens and 9.6 cm$^2$ for steel specimens.

## Results and discussions

The influence of the pressure and contact time on the tensile strength was performed on wood and steel substrates.

The dependence of the stress on contact time was performed on oak tree specimens and the results are shown in figure 1. The correlation of the maximum force with the specimen surface (12.56 cm$^2$) allowed the evaluation of the tensile strength as a function of contact time (fig. 2).

Data from figure 1 and 2 reveal the strong influence of the contact time on the tensile strength of the adhesive assembly, which is in good agreement with literature data for other types of pressure sensitive adhesives [3, 14].

The dependence of the tensile stress on applied contact pressure for wood and steel substrates is presented in figure 3 and 4. The correlation of the maximum force to the specimen surface allowed the evaluation of the tensile

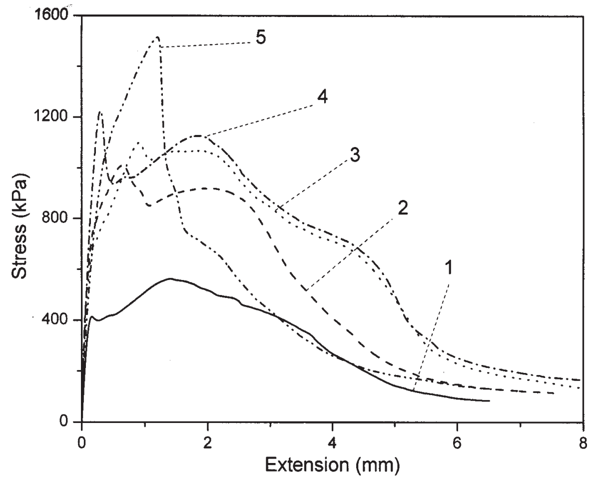


Fig.3. Influence of the contact pressure on tensile stress for wood/ wood assembly
Temperature 25 °C, relative humidity RH 50 %, bonding surface 12.56 cm$^2$, contact time 7 days, rate of separation 2 mm/min
1 – p=1.6 N/cm$^2$; 2 – p=4 N/cm$^2$; 3 – p=8 N/cm$^2$; 4 – p=12 N/cm$^2$; 5 – p=16 N/cm$^2$

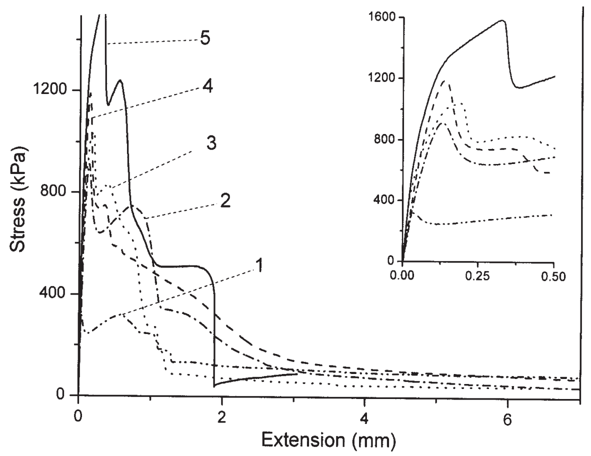


Fig.4. Dependence of the tensile stress on the contact pressure for steel/steel assembly
Temperature 25 °C, relative humidity RH 50 %, bonding surface 9.6 cm$^2$, contact time 7 days, rate of separation 2 mm/min
1 – p=2.1 N/cm$^2$; 2 – p=5.2 N/cm$^2$; 3 – p=10.4 N/cm$^2$; 4 – p=15.6 N/cm$^2$; 5 – p=20.8 N/cm$^2$

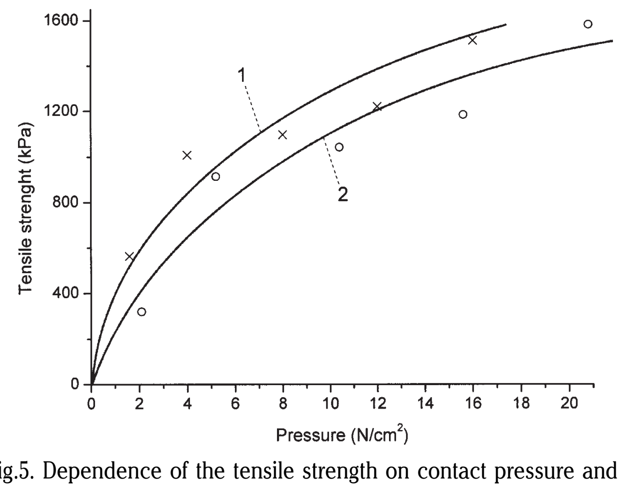


Fig.5. Dependence of the tensile strength on contact pressure and nature of the substrate 1 – wood/wood, 2 – steel/steel

strength as a function of applied pressure (fig. 5). Results from figure 3-5 reveal the influence of the contact pressure on tensile strength. It is shown that the tensile strength for

| No. | Contact force, N | $\sigma_{max}$, kPa | | W, kJ/m$^2$ | |
|---|---|---|---|---|---|
| | | Wood/wood | Steel/steel | Wood/wood | Steel/steel |
| 1 | 20 | 563 | 321 | 2146 | 911 |
| 2 | 50 | 1009 | 915 | 3825 | 995 |
| 3 | 100 | 1098 | 1044 | 5043 | 1419 |
| 4 | 150 | 1222 | 1187 | 5215 | 1704 |
| 5 | 200 | 1515 | 1586 | 3412 | 1559 |

**Table 2**
VALUES of $\sigma_{max}$ AND W AS A FUNCTION OF PRESSURE AND NATURE OF THE SUBSTRATE

wood specimens is higher than those for steel specimens but they have the same order of magnitude.

Stress-extension curves ($\sigma$–$\delta$) shown in figure 4 and 5 are characterized by two parameters: maximum stress ($\sigma_{max}$, adhesion strength) and the separation energy (W, area under the curve) [26, 27].

$$W = \int_0^{\delta_{max}} \sigma(\delta)\, d\delta \qquad (1)$$

This separation energy W is different from the adhesion thermodynamic work $W_a$. Thermodynamic work ($W_a$) is computed from the contact angle and superficial tension as reported for shear tests [2].

The values for $\sigma_{max}$ and W of the adhesive assemblies based on wood and steel substrates are shown in table 2.

The data from table 2 show the increase of the tensile stress ($\sigma_{max}$) with contact pressure. The same phenomenon is observed for the separation energy W. Nevertheless, this increase in the separation energy is limited to 150 N contact pressure. After this value, the separation energy for both specimens decreases and this could be explained by higher de-bonding strength. The fracture mechanism is faster as this process has started and the area under the stress-strain curve diminishes.

The tensile breaking mechanism of the adhesive assembly could be elucidated by optical means at narrow time intervals (fig. 6).

One may notice from figure 6 a four-step tensile breaking. First step (fig. 6.1) consists in the initiation of the

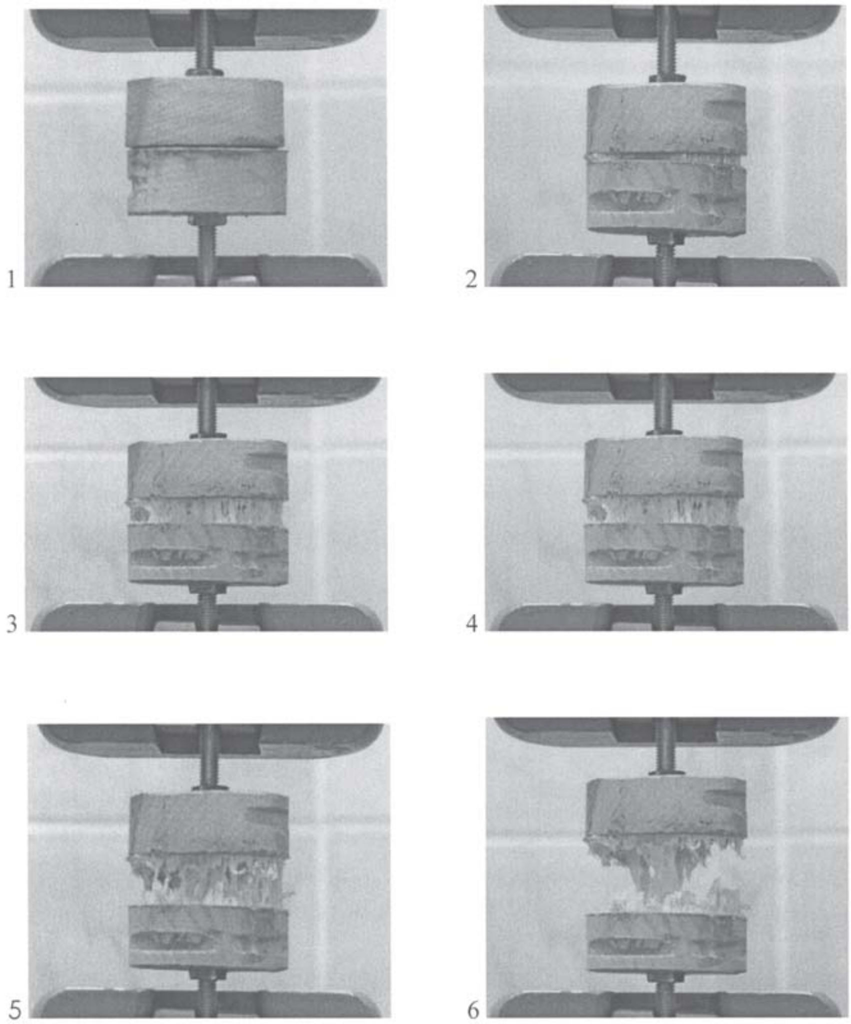


Fig.6. Steps of the tensile breaking mechanism of the adhesive assemblies between wood substrates

breaking process of the adhesive assembly accompanied by very low deformations. Next small cavities in the adhesive layer are observed (fig. 6.2). Third stage consists in formation of an expanded fibrilar structure by elongation of the cavities normally to the adhesive pellicle (fig. 6.3 and 6.4). The final step consists in the breaking of the fibrils and separation of the two substrates (fig. 6.5 and 6.6).

As shown in figure 6 the breaking starts between the adhesive and substrate (I and II) – adhesive breaking, and when the fibrils are broken and the substrates are separated the cohesive breaking takes place.

## Conclusions

The studies regarding the tensile strength of the adhesive assemblies based on pressure sensitive adhesives with polychloroprene rubber on wood and steel substrates led to the following conclusions:

-the tensile strength depends on the contact time, the best performances being obtained after 7 days;

-the tensile strengths of adhesive assemblies on wood substrates are higher than those on steel substrates;

-the contact pressure is the major factor that influences the tensile strength of the adhesive assembly. This aspect is illustrated by the values of $\sigma_{max}$ and W;

-the breaking of the adhesive assembly takes place within the adhesive layer (cohesive breaking) in a four-step process.

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Manuscript received: 19.05.2011