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ABOUT METAL-RUBBER ADHERENCE

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ABSTRACT
In this paper we analyze both under theoretical aspects and practical aspects related to rubber adherence with metal. In the first part we make a theoretical presentation of force type that characterize phenomenons of adherence and degree measures of force in relation with distance between both surface (rubber-metal). In the second part we present aspects related to practical modalities to determine metal-rubber adherence. In the next part we compare the practical modalities to determine adherence and after that we compare the results.
Keywords: adherence, rubber, interfacial forces.

1. INTRODUCTION
The adherence phenomenon corresponds the states in which the two surfaces are maintained adjacent with interfacial forces. Complying with the definition of adherence phenomenon, the adhesive term will be attributed to the substance that is capable to unite those two bodies by fixing them on the surface and the adhesive term should be understand reflecting the intrinsic interactions from the interface, and it is synonym with the thermodynamically adherence work. In this paper we analyze the adherence process both under theoretical and experimentally aspects.

2. THEORETICAL ASPECTS
In paper [2] we show that, if you assure a contact (rubber-metal) interfacial closely enough, there will appear leakage interactions characterized by a type of forces with universal characteristics named London forces. These leakage forces are additives, a molecule incurs all the molecules neighboring with it. To find the expression of the potential energy that characterize this type of interaction, we consider that atoms or molecules that compose the dipoles have sphere shape, like in figure 1.

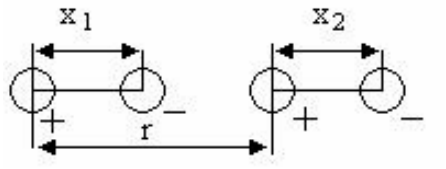

Figure 1. Dipoles

Potential energy relation [1] of interaction between the dipoles presented in figure 1 is:

$$U_{1,2}(r) = -\frac{2q^2 x_1 x_2}{4\pi\varepsilon_0 r^2}. \qquad (1)$$

where: q is the charge that are loaded the particles that compose the dipoles; x_1, x_2 – dipoles arms; r – distance between those two dipoles; ε_0 – electrical permitivity of the inanity.
In the case when between the dipoles do not interact and every dipole harmonic oscillates, the frequency is given by the relation:

$$\nu_0 = \frac{1}{2\pi}\sqrt{\frac{f}{m}}, \qquad (2)$$

where f is a cvasielastic constant and m is the dipole mass.
Because of the charges movement that compose the dipole it will appear the cvasielastic forces $-fx_1$ and $-fx_2$. Between these two dipoles actionate the interaction forces F_{12} and F_{21} that can be obtained from interaction potential energy relation U_{12} as in (6) relation, with the relations:

$$F_{12} = -\frac{\partial U_{12}}{\partial x_1} = \frac{2q^2 x_2}{4\pi\varepsilon_0 r^3};\ F_{21} = -\frac{\partial U_{12}}{\partial x_2} = \frac{2q^2 x_1}{4\pi\varepsilon_0 r^3}.$$

Because both F_{12} and F_{21} forces are having an elastically nature we can calculate them with the relation:

$$F = -kx = -\frac{2q^2 x}{4\pi\varepsilon_0 r^3} \Rightarrow k = \frac{2q^2}{4\pi\varepsilon_0 r^3}, \tag{3}$$

where k represents elastic constant.
The movement laws of those two oscillators are having this form:

$$\ddot{x}_1 + \omega_0 - \frac{k}{m} = 0;\ \ddot{x}_2 + \omega_0 - \frac{k}{m} = 0. \tag{4}$$

The solution of these two equations are:

$$x_1 = Ae^{i\omega t} \text{ and } x_2 = Be^{i\omega t}.$$

Introducing these solution in equation (4) and resolving the equations system we obtain:

$$\omega_{12} = \sqrt{(\omega_0^2 \mp k/m)}. \tag{5}$$

In quantum mechanics harmonic oscillators energy is given by the relations:

$$E_{n1} = h\nu_1\left(n_1 + \frac{1}{2}\right);\ E_{n2} = h\nu_2\left(n_2 + \frac{1}{2}\right), \tag{6}$$

where: h is Planck's constant; $\nu_{1,2} = \frac{\omega_{1,2}}{2\pi}$, the oscillating frequencies (dipoles); $n_{1,2}$ oscillators excitation levels.
Total energy is given by the relation:

$$E = E_{n1} + E_{n2}. \tag{7}$$

Considering that the oscillators are on the fundamental level ($n_1 = n_2 = 0$), using the dependence of the frequency and pulsation and using the relations (5), (6), (7), the total energy can be written as:

$$E = h\nu_0\left(1 - \frac{q^2}{2(4\pi\varepsilon_0)^2 r^6 f^2}\right) = h\nu_0 - \frac{A}{r^6}, \tag{8}$$

where A is a constant that can be calculated from the spectroscopy dates.
In relation (8) the first term represents the potential energy of the rejected forces and the second term represents the potential energy of the attraction forces. The fact that the energy characterizes the dispersion interactions has minus means that the particles mutual attracts in all the cases.

These forces are enough for a strong adhesion 10^8….10^{10} N/m^2 at distance of 0,4 – 0,5 *nm*, 10^7…10^9 N/m^2 at 1 *nm* şi 10^4..10^6 N/m^2 at approximately 10 *nm* for metals, approximately with a measure order lower than the dielectrics and intermediary at metal-dielectric contacts.

3. EXPERIMENTAL CHECKINGS

At macroscopic scale metal-rubber adherence is determine in different ways. In laborator control rubber mixtures, adhesives and tehnological fabricating proceedings, adherence is checked up on the epruvets (fig. 2).

The epruvet is made with the next components:

1 – rubber,
2 – metal plate.

Fixation device is composed:

- A – piece for interface connector of the fixation device at attempted machine;
- B – ladder for sustaining A piece and in which we install C piece;
- C – piece with a central place in which we install epruvet.

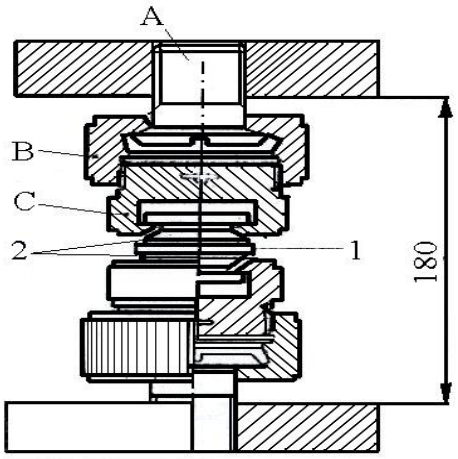

Figure 2. Lab device for adherence determination

The epruvet is composed from a rubber disk with thickness of 3 *mm*, diameter of 35…..40 *mm* and it's faces must be adhere at two metallic plates with the same diameter and thickness of minimum 9 *mm* [6]. Metal plates are made from carbonate steel laminated or same metal that compose the rubber piece armature, and metal plate surfaces are drawn after the same ethnologic process as that piece armatures. Temperature and vulcanization duration are chosen in optimal conditions to vulcanize, for the rubber piece or for the adherence system that we study.
Fixing epruvet is made so that the tension can be uniform distribute on the epruvet. The traction force applied is constant, and the separation speed of 25 *mm*/*min*. This force operates until the brake of rubber-metal adherence.

Adherence (*A)* is obtained with the relation: $A = \frac{F}{S}$,

in which: *F* is the braking force; *S* – initial surface of the stacked area.

Table 1 Values for adherence determination

Nr.crt	$S[10^{-4}m^2]$	$F[10^4N]$	$A\ [10^6N/m^2]$	$A_{med.}[N/m^2]$
1	12,56	2,51	20	$19{,}66 \cdot 10^6$
2	12,56	2,26	18	$19{,}66 \cdot 10^6$
3	12,56	2,63	21	$19{,}66 \cdot 10^6$

We observe that the experimental resulted value is the same with those of the London force per surface unit, specified in the theoretical part when the distance between those two surfaces in approximately 1 *nm.* Another way to experimental determine of adherence is obtained by monoaxial compression variable on a hidro-puls of a metal-rubber piece at which we draw braking adherence diagram.
Rubber – metal piece is constrained to a monoaxial compression on a special stand and because of that we draw braking adherence diagram (fig. 3). Movement speed at jack's compression is constant and has the value $v = 0{,}5 \cdot 10^{-3}$ *m/s*.

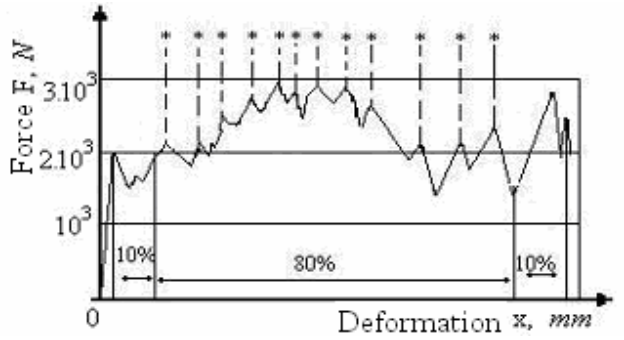

Figure 3. Braking diagram of metal-rubber adherence at one piece

Related with the braking diagrams we can say:

- braking of the adherence first appears at the superior end of the elastic element because the tensions distribution at shearing is not uniform on contact surface, because of the rubber elasticity.
- fissure propagates down, with rubber fall out and adherence, fact that gives an jag aspect to diagram.

We observe that this diagram posesed less than 20 tops, wich means that force's median is calculated with the help of the tops from the central side [1].

Table 2 Values of the force in those 20 tops.

$F_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots F_{12}\,[N]$	$F = \frac{\sum_{i=1}^{12} F_i}{12}\,[N]$	$S = \pi dl\ [m^2]$	$A = \frac{F}{S}$ $[N/m^2]$
2076,2077,2500,2750,2900,2700, 2800,2500,2076, 2080,2400,2700	2463	$2241{,}9 \cdot 10^{-6}$	$1{,}098 \cdot 10^{6}$

Knowing for metal-rubber piece (jack) values of d = 30 *mm* and l = 23,8 *mm* and tops values from the other side of diagram and processing the values from table 2, we obtain real value of adherence.

4. CONCLUSIONS

Bound to the theoretical aspects presented and experimentally determined you can conclude:

- the adhesion process it can base on the diffusion process;
- diffusion can be considered only if we admit that it exists a contact area where the London forces manifests.

We observe that obtained value of adherence direct on piece is lawer than the value obtained on epruvet. This un-correspondence apears because of some factors like:

- adherence surface flexing,
- tensions concentration,
- lawer vulcanization speed.

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