THE EVALUATION OF RUBBER BLENDS HOMOGENEITY FROM MEASUREMENTS OF D.C. AND A.C. ELECTRICAL CONDUCTIVITY

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ABSTRACT
Homogeneity of rubber samples is important factor in tire and tire production. It can influence on the other properties, like adhesion, vulcanization properties, physical and mechanical properties. The work presents results of the study of structural inhomogeneities of rubber blends. Both direct current and alternating current electrical measurements were used to evaluate the electrical properties for sample of the same composition and compared with those of atomic force microscope /AFM/.
Keywords: conductivity, inhomogeneity, rubber sample

1. INTRODUCION
Homogeneity of rubber samples, which are used in rubber industry, especially in car tyre production, is very important factor. Nevertheless, after more than two hundreds years of tyre production is the technology of rubber blend mixing still actual and intensively developed process All of used rubber blends are prepared in the mixing chamber the mixer realized by screw mechanism and extrusion [1], where there are mixed together following “recipe” chemicals during conditions /pressure, temperature, time/.
Worse dispersion of some chemicals, especially fillers /carbon black or SiO_2/ can effects breaking of tyre components /initializing of micro cracks/, breaking of tyre /initializing of macro cracks/. For optimal mechanical properties, the homogeneous dispersion and distribution of the carbon black in the polymer phases are of particular importance [2].
The testing of rubber blends homogeneity is realized by measurement of D.C. /direct current/ and A.C. /alternating current/ conductivity.
Using of simple apparatus, which is illustrated on the picture, tests D.C. electrical conductivity [3].

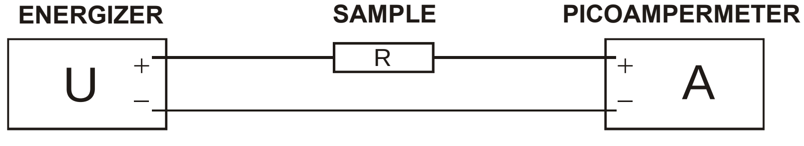

Figure 1. Schema of the D.C. conductivity apparatus

We measured temperature – conductivity dependence of 3 samples. These were cut from the big rectangular rubber plate /diameter 12mm, thickness 2,3mm/, from various places – see the picture.

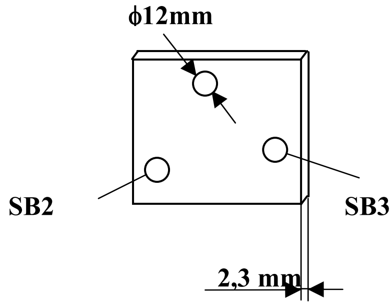

Figure 2. Schema of the mother sample

Measured values of current, temperature, voltage and calculated values as conductivity are in tables 1-3.

Table 1. Measured values of D.C. for SB1 sample

SB1	t [°C]	I [nA]	ρ [Ωm]	σ [Ωm]$^{-1}$	ln σ	10^3/T [K]$^{-1}$
1	76	13,05	7,91E+08	1,264E-09	-20,4892	2,87
2	72	12,87	8,02E+08	1,246E-09	-20,5031	2,90
3	68	11,86	8,71E+08	1,149E-09	-20,5848	2,93
4	64	9,10	1,13E+09	8,812E-10	-20,8497	2,97
5	60	4,32	2,39E+09	4,183E-10	-21,5947	3,00
6	56	3,95	2,61E+09	3,825E-10	-21,6843	3,04
7	52	2,66	3,88E+09	2,576E-10	-22,0797	3,08
8	48	1,22	8,46E+09	1,181E-10	-22,8591	3,12
9	44	0,39	2,65E+10	3,777E-11	-23,9996	3,15
10	40	0,37	2,79E+10	3,583E-11	-24,0522	3,19

Table 2. Measured values of D.C. for SB2 sample.

SB2	t [°C]	I [nA]	ρ [Ωm]	σ [Ωm]$^{-1}$	ln σ	10^3/T [K]$^{-1}$
1	66	11,20	9,22E+08	1,085E-09	-20,6421	2,95
2	64	10,06	1,03E+09	9,742E-10	-20,7494	2,97
3	62	8,90	1,16E+09	8,619E-10	-20,8719	2,99
4	60	7,50	1,38E+09	7,263E-10	-21,0431	3,00
5	58	6,10	1,69E+09	5,907E-10	-21,2497	3,02
6	54	5,40	1,91E+09	5,229E-10	-21,3716	3,06
7	52	4,05	2,55E+09	3,922E-10	-21,6593	3,08
8	50	3,30	3,13E+09	3,196E-10	-21,8641	3,10
9	48	2,10	4,92E+09	2,034E-10	-22,3160	3,12
10	46	0,90	1,15E+10	8,715E-11	-23,1633	3,13

Table 3. Measured values of D.C. for SB3 sample

SB3	t [°C]	I [nA]	ρ [Ωm]	σ [Ωm]$^{-1}$	ln σ	10^3/T [K]$^{-1}$
1	74	12,96	7,97E+08	1,255E-09	-20,4961	2,88
2	70	11,80	8,75E+08	1,143E-09	-20,5899	2,92
3	66	10,94	9,44E+08	1,059E-09	-20,6656	2,95
4	64	10,50	9,83E+08	1,017E-09	-20,7066	2,97
5	60	8,75	1,18E+09	8,473E-10	-20,8889	3,00
6	58	6,22	1,66E+09	6,023E-10	-21,2302	3,02
7	54	4,90	2,11E+09	4,745E-10	-21,4687	3,06
8	50	3,30	3,13E+09	3,197E-10	-21,8641	3,10
9	46	1,42	7,27E+09	1,375E-10	-22,7073	3,13
10	44	0,87	1,19E+10	8,425E-11	-23,1972	3,15

RCL programmable meter measures A.C. electrical parameters using of 4-wire test cable PM 9540/BAN that is direct connected with PC. For these measurements was necessary to create the software for electric values monitoring [4].

Figure 3. Schema of the A.C. conductivity apparatus

Using of this apparatus is possible to measure the electric parameters by various frequencies. From the values as resistance, capacity, impedance, dissipation, quality, phase angle, we can calculate real and imaginary part of complex modulus and conductivity values. On the next figures / figure 4 – 7/ are to seen the electrical parameters dependencies.

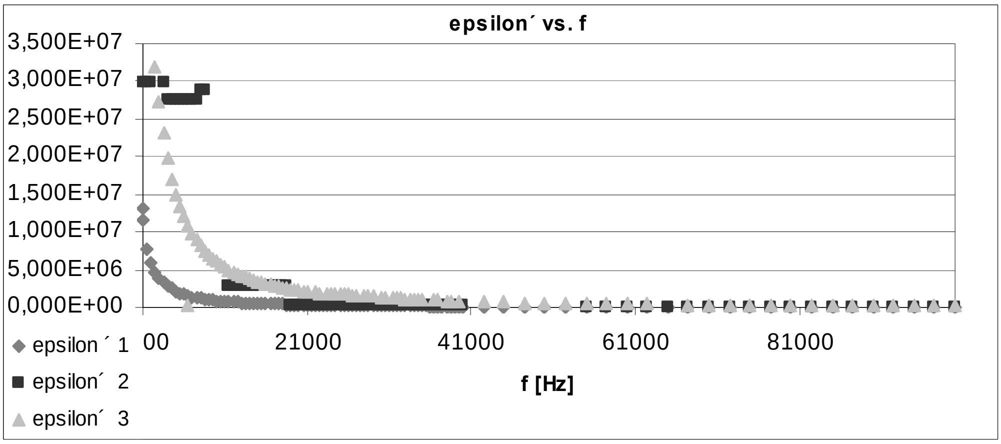

Figure 4. Dependence: real part of complex modulus versus frequency

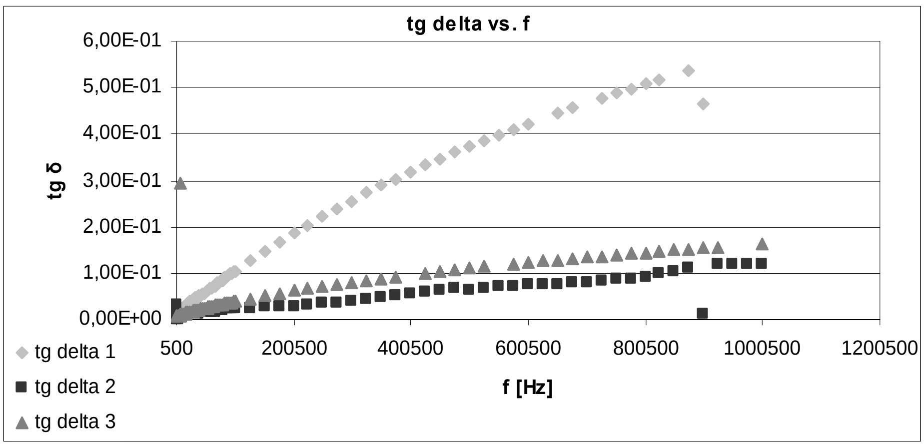

Figure 5. Dependence: tg δ versus frequency

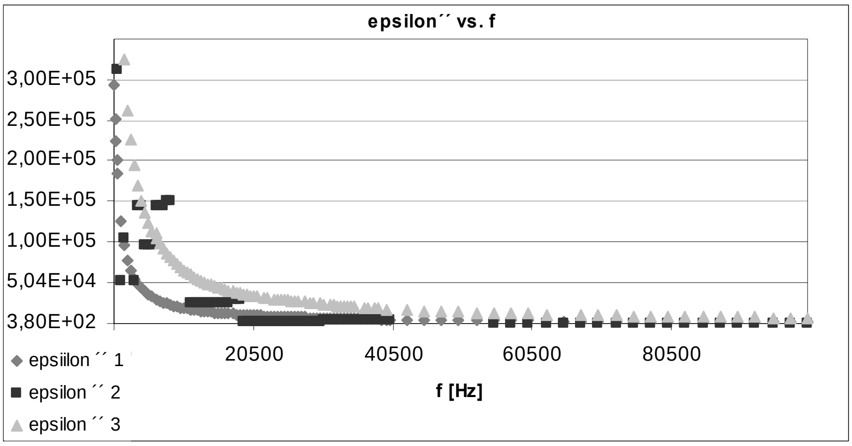

Figure 6. Dependence: imaginary part of complex modulus versus frequency

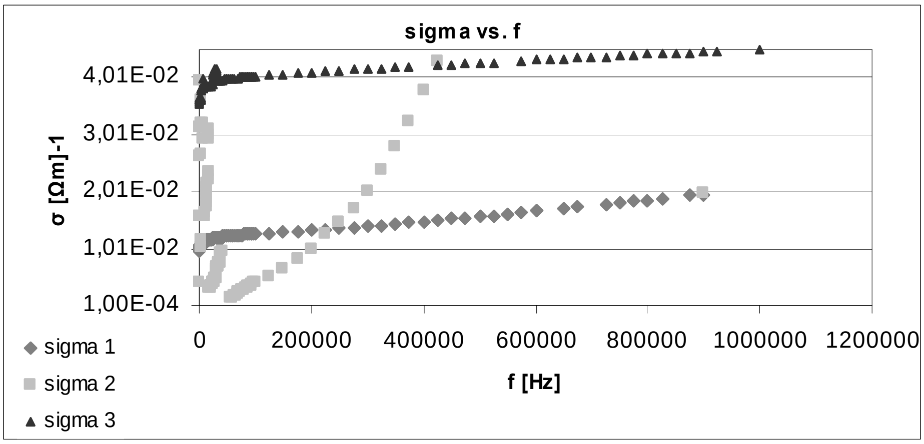

Figure 7. Dependence: conductivity versus frequency

At last was homogeneity of described samples evaluate by AFM /atomic force microscope/. AFM visualization Van der Waals forces are only one factor of bracket deviation affecting. Thin layers of moisture that are usually present at working with AFM in the presence of air and also streaks and impurities will also influence the measurement. Samples SB1-SB3 are shown in figures 8-10.

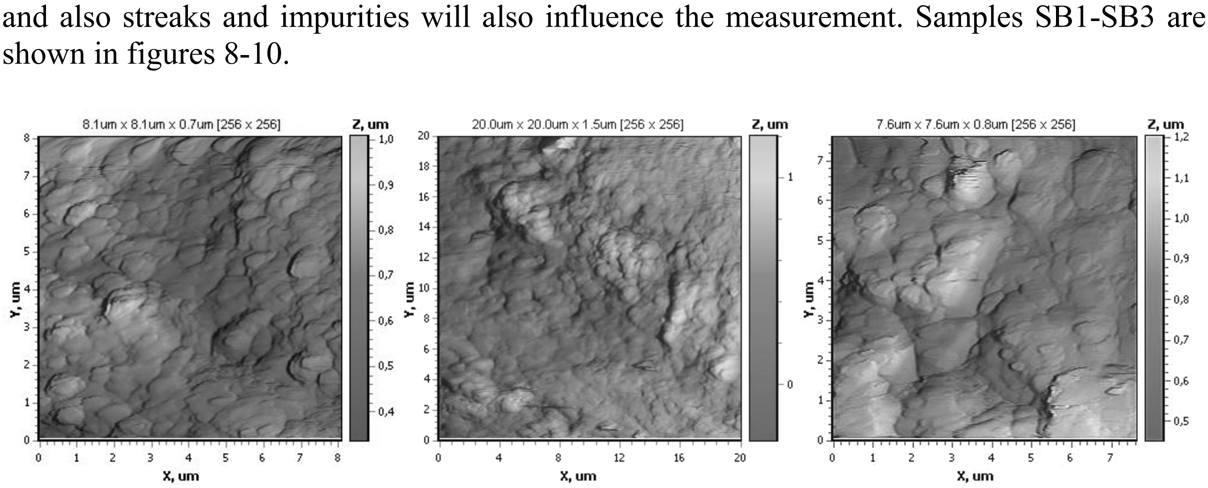

Figure8. AFM evaluation of SB1 Figure9. AFM evaluation of SB2 Figure10. AFM evaluation of SB3.

The bright and dark places represent different large distribution of Van der Waals forces, which are presented in Figures 8-10. It is caused by worse dispersion of carbon black, which was used as an ingredient - filler for mixture preparing. Only one sample SB and its cut parts - samples SB1, SB2 and SB3 allocate so large differences.

2. SUMMARY

From results is obviously, that samples SB1 – SB3 are strong inhomogeneous. Used methods like measurement of D.C. and A.C. conductivities are very sensitive for that indication.
Very similar is AFM finally evaluation. The interesting way of rubber blends control is on-line conductivity monitoring of "mixing mass" into mixing chamber, /observation its behavior and mass properties during mixing /. It is the first step to mixture quality control – and waste reduction.

3. REFERENCES:

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