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## Elastomeric composites filled with magnetic hard fillers

*In this work elastomeric magnetic materials were prepared by incorporation of strontium ferrite as magnetic filler in rubber compounds based on natural as well as butadiene rubber. The focus of the work is aimed at a preparation of elastomeric magnetic composites and evaluation of magnetic filler influence on curing characteristics, physical-mechanical and magnetic properties of prepared composites. The study is also dedicated to the cross-link density and sulfur cross-link structure of vulcanizates. The results achieved by the study point out the possibilities of preparation of elastomeric magnetic composites by the processes generally used in rubber technology. The prepared materials have suitable magnetic and elastic properties.*

**Key words:** polymer composites, magnetic filler, curing characteristics, physical-mechanical properties, cross-link structure

## Kompozyty elastomerowe zawierające napełniacze ferromagnetyczne

*W przedstawionej pracy otrzymano materiały o właściwościach magnetycznych uzyskiwanych przez dodatek napełniacza magnetycznego – żelazianu (III) strontowego (ferrytu strontowego) – do mieszanek gumowych zawierających kauczuk naturalny, jak również butadienowy. Badania koncentrują się na przygotowaniu elastomerowych kompozytów magnetycznych i ocenie wpływu napełniacza magnetycznego na charakterystykę wulkanizacji oraz na właściwości mechaniczne i magnetyczne tych kompozytów. Dotyczą także gęstości usieciowania i struktury wiązań siarkowych w wulkanizatach. Uzyskane w trakcie badań wyniki wykazują możliwości wytwarzania elastomerowych kompozytów magnetycznych w procesach powszechnie stosowanych w technologii gumy. Uzyskane materiały mają odpowiednie właściwości magnetyczne i elastyczne.*

**Słowa kluczowe:** kompozyty polimerowe, napełniacz magnetyczny, charakterystyka wulkanizacji, właściwości mechaniczne, struktura usieciowania.

### 1. Introduction

Nowadays, more and more attention is given to the preparation and study of elastomeric composites with magnetic properties. Elastomeric magnetic composites consist of two main components: magnetic powder (filler) and polymer matrix (rubber blend) [1-5]. The two different elements are attended to one structural unit, what brings new technological abilities and properties. In magnetic composite materials, the magnetic filler is distributed in polymer matrix; these materials are characterized by interesting mechanical, chemical and rheological properties. The advantages of elastomeric magnetic composites are that their properties can be modified for the requirements of specific applications. These materials exhibit very good magnetic properties, elasticity and easy mouldability. Rubber magnets can

absorb shock and sound, so they can be applied in dc-motors, motor parts, memo holders, electromagnetic absorbers, intelligent tyres, sensors of magnetic fields, in microwave and radar technology, also in other technological applications.

Metal ferrites with general formula  $MFe_{12}O_{19}$  (M is divalent cation such as Ba, Sr, ect.) belong to the widely used magnetic materials. In term of technological applications one may distinguish between two main types of ferrites, hard ferrites and soft ferrites. Soft magnets are materials characterized by domain walls which can be easily moved when a magnetic field is applied. Magnetic soft materials have narrow hysteresis loop and low value of remanent magnetic induction  $B_r$ . Those with less mobile domain walls are termed hard magnets. Magnetic hard materials have wide hysteresis loop and value of coercivity  $H_c > 2.5 \text{ kA} \cdot \text{m}^{-1}$ . They also exhibit high value of remanent magnetic induction  $B_r$  and high value of maximum energy product  $(BH)_{\text{max}}$ . These ferrites with hexagonal structure are suitable for producing of permanent magnets [6-8]. Because of low price and very good chemical stability ferrites are included in the most important magnetic materials, which cannot be easily replaced. Ba and Sr ferrites are the most common applied magnetic powder fillers.

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## 2. Experimental

### 2.1. Materials

The two types of elastomers, natural rubber (NR) SMR 20 (MARDEC, Malaysia) and solution high-*cis*-1,4 butadiene rubber (BR) Buna CB 24 (*cis*-1,4 content 96%, Mooney viscosity ML(1+4)100°C=44, Lanxess, Germany) were filled with ferromagnetic particles in order to prepare elastomeric magnetic composites. A standard sulfur-based vulcanization system (sulfur – 1.3 phr, N-cyclohexyl-2-benzothiazolsulfenamide – 1.5 phr,

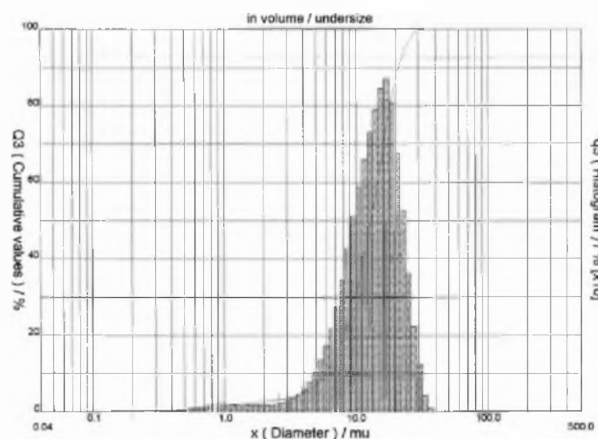


Figure 1. Particle size distribution of strontium ferrite  
Rysunek 1. Rozkład wielkości cząstek ferrytu strontowego

ZnO – 3 phr, stearin – 2 phr) was used. Anisotropic strontium hexaferrite SrFe<sub>12</sub>O<sub>19</sub> type FD 8/24 prepared by wet milling (MAGNETY, Světla Hora, Czech Republic) was applied as magnetic filler. It is a product with additional polyvinyl alcohol, which covers the surface of ferrite particles. Ferrite, which was used in our experiments, was prepared by dissolution of polyvinyl alcohol by extraction in hot water. After removal of polyvinyl alcohol, particles size of ferrite was reduced. The content of ferrite in both types of rubber compounds varied from 0 to 100 phr. Detailed specification of magnetic filler is mentioned in Figure 1 and Table 1.

Table 1. Characteristics of strontium ferrite  
Tabela 1. Właściwości ferrytu strontowego

Characteristics	Values
Density $\rho$ , g·cm <sup>-3</sup>	4.73
Specific surface area, m <sup>2</sup> ·g <sup>-1</sup>	4.06
Total porosity, %	55.62
Coercivity, kA·m <sup>-1</sup>	117
Remanent magnetic induction, T	0.170

### 2.2. Methods

The rubber compounds were prepared in the laboratory mixer BRABENDER in two mixing steps. In the first step the rubber and the filler were compounded (9 min, 90°C), in the second step (4 min, 90°C) curing system was added. The compounds were cured at 150°C for the optimum cure time  $t_{c90}$  by using the hydraulic press FONTUNE. Physical-mechanical properties of the prepared vulcanizates were measured in accordance with the valid technical standards, on the double side blade specimens (width 6.4 mm, length 10 cm, thickness 2 mm). Magnetic measurements of vulcanizates on the magnetometer TVM-1 at room temperature were determined.

The two different methods were used in order to determine cross-link density of vulcanized samples:

1. equilibrium swelling in xylene ( $v_{ch}$  – chemical cross-link density), using the Krause modified Flory-Rehner equation (1) for filled vulcanizates [9]:

$$v_{ch} = -\frac{V_{r0}}{V_S} \frac{\ln(1-V_r) + V_r + \chi V_r^2}{V_r^{1/3} V_{r0}^{2/3} - 0,5 V_r} \quad (1)$$

$v_{ch}$  – cross-link density (mol·cm<sup>-3</sup>)

$V_{r0}$  – volume fraction of rubber in equilibrium swelling sample of vulcanizate in absence of fillers

$V_r$  – volume fraction of rubber in equilibrium swelling sample of filled vulcanizate

$V_S$  – molar volume of solvent (for xylene = 123.45 cm<sup>3</sup>·mol<sup>-1</sup>)

$\chi$  – Huggins interaction parameter

2. deformation measuring ( $v_t$  – total cross-link density) by means of the Mooney-Rivlin equation (2), utilizing relation (3), too:

$$\frac{\sigma}{2(\alpha - \alpha^{-2})} = C_1 + \frac{C_2}{\alpha} \quad (2)$$

$\sigma$  – tension,  $\alpha$  – relatively extension,  $C_1$ ,  $C_2$  – constants

$$v_c = 2C_1 / RT \quad (3)$$

$R = 8,314 \text{ J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$ , measuring temperature  $T = 293.15 \text{ K}$

The measurements were carried out in the INSPEKT desk 5 kN apparatus (METROTEST), up to 100% deformation, deformation velocity of 10 mm·min<sup>-1</sup>.

The cross-link structure was evaluated using the thiol-amine method in argon atmosphere, at laboratory temperature, 2 or 48 h, respectively [10-12].

## 3. Results and discussion

### 3.1. Influence of ferrite on curing process of rubber compounds

The influence of magnetic filler content on basic curing characteristics, e.g. the scorch time  $t_{S1}$  and the opti-

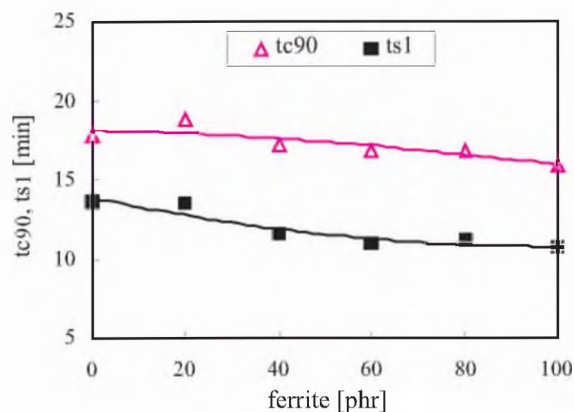


Figure 2. Influence of ferrite content on scorch time  $t_{s1}$  and optimum cure time  $t_{c90}$  of NR-rubber compounds  
Rysunek 2. Wpływ zawartości ferrytu na czas podwulkanizacji  $t_{s1}$  i optymalny czas wulkanizacji  $t_{c90}$  mieszanek gumowych NR

imum cure time  $t_{c90}$  was assessed. The difference between maximum and minimum torque  $\Delta M$ , the curing rate  $R'$  and the curing rate index  $R_v$  were investigated, too. The values of these parameters were determined from the corresponding curing isotherms measured at 150°C by using the Rheometer Monsanto S100. From Figure 2 it is seen that the presence of ferromagnetic filler leads to a decrease of optimum cure time as well as the scorch time of composites based on natural rubber. The  $t_{c90}$  of maximum filled composite decreased in about 10% and  $t_{s1}$  in about 21% in comparison with  $t_{c90}$  or  $t_{s1}$  of ferrite free sample. The values of  $\Delta M$  by contrast exhibit an increasing tendency with increasing of magnetic filler content (nearly 40%). The curing rate index  $R_v$  decreases in the presence of 20 phr of ferrite, but with the next increasing of ferrite loading, the  $R_v$  values fluctuates in the low range, almost independently on the amount of magnetic filler. The influence of applied filler content was not observed in case of the curing rate  $R'$ ,

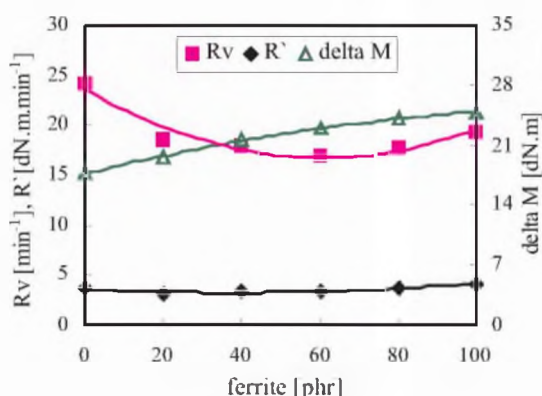


Figure 3. Influence of ferrite content on  $\Delta M$  value, curing rate  $R'$  and curing rate index  $R_v$  of NR-rubber compounds  
Rysunek 3. Wpływ zawartości ferrytu na wartość  $\Delta M$ , szybkość wulkanizacji  $R'$  i wskaźnik szybkości wulkanizacji  $R_v$  mieszanek gumowych NR

which seem to have very similar values in all cases (Fig. 3).

The similar decreasing tendency with increasing of ferrite loading was recorded also in case of  $t_{c90}$  and  $t_{s1}$  of BR-composites (Fig. 4). In comparison with unfilled sample used as reference, the addition of magnetic filler caused the reduction of  $t_{c90}$  from about 28 to approxi-

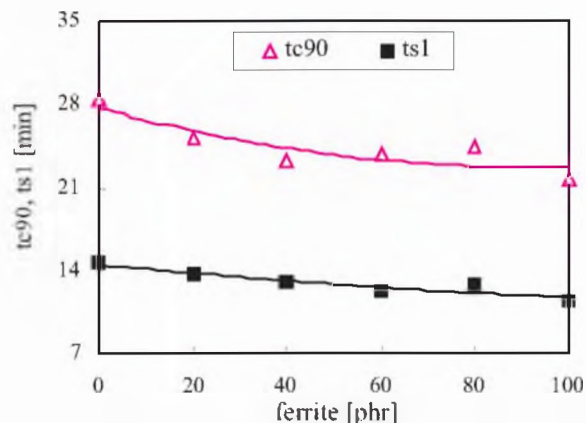


Figure 4. Influence of ferrite content on scorch time  $t_{s1}$  and optimum cure time  $t_{c90}$  of BR-rubber compounds  
Rysunek 4. Wpływ zawartości ferrytu na czas podwulkanizacji  $t_{s1}$  i optymalny czas wulkanizacji  $t_{c90}$  mieszanek gumowych BR

mately 22 minutes (for the composite with 100 phr of ferrite). The  $t_{s1}$  was reduced from about 15 minutes to 11 minutes. Simultaneously, not only the extend of  $\Delta M$  value increased in about 20%, the curing rate index  $R_v$  increased as well in about 33% (Fig. 5). It is evident, that above mentioned changes have their origin in acceleration of the cross-linking process in rubber blends as an effect of used filler. Taking into consideration that rubber blends differ in ferrite loading only (content and

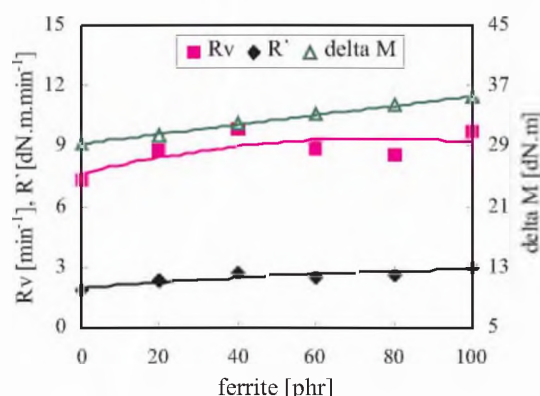


Figure 5. Influence of ferrite content on  $\Delta M$  value, curing rate  $R'$  and curing rate index  $R_v$  of BR-rubber compounds  
Rysunek 5. Wpływ zawartości ferrytu na wartość  $\Delta M$ , szybkość wulkanizacji  $R'$  i wskaźnik szybkości wulkanizacji  $R_v$  mieszanek BR

composition of the vulcanization system was constant without any other ingredients) all changes in evaluated curing characteristics are attributed to the effect of magnetic filler.

### 3.2. Influence of ferrite on elastomeric composites properties

The work was also focused on the study of the influence of ferrite loading on basic physical-mechanical and magnetic properties of cured rubber compounds. The achieved results showed that ferrite present in NR-vulcanizates has an influence on moduli especially, which increase substantially with increasing of ferrite content. The increase of modulus M100 represents approximately 74%, M200 77%, M300 89% and M500 96% of corresponding moduli values of ferrite free sample (Fig. 6). On the other hand the elongation at break was found to decrease with increasing amount of ferrite. At maximum ferrite loading it decreases about 17% in comparison to unfilled sample (Fig. 7). From Figure 7 also becomes evident, that the influence of magnetic filler loading on the tensile strength was insignificant.

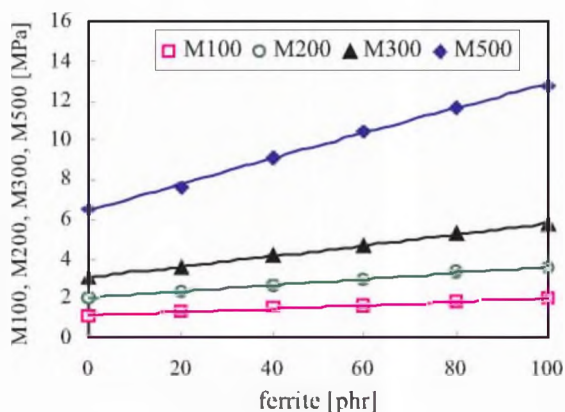


Figure 6. Influence of ferrite content on moduli M100, M200, M300 and M500 of NR-vulcanizates  
Rysunek 6. Wpływ zawartości ferrytu na moduły M100, M200, M300 i M500 wulkanizatów NR

Figure 8 shows the influence of ferrite content on physical-mechanical properties of vulcanizates based on butadiene rubber. Despite that the values of physical-mechanical properties of BR-vulcanizates were relatively small, from the experimental data there is obvious, that the presence of ferrite in elastomeric matrix leads to enhancement of evaluated characteristics. From the Figure 8 it is observable non-linear increase of the tensile strength at break as a function of ferrite loading. The increase of the tensile strength value of vulcanizate filled with maximum ferrite content represents more than 75% in comparison with the tensile strength value of ferrite free vulcanizate. The increasing tendency on magnetic filler content was detected also in case of elonga-

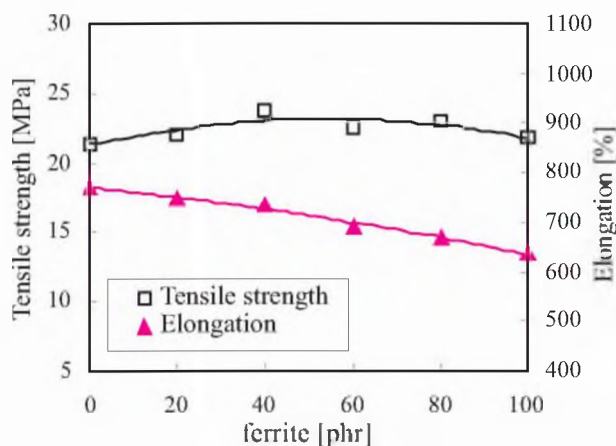


Figure 7. Influence of ferrite content on tensile strength at break and elongation at break of NR-vulcanizates  
Rysunek 7. Wpływ zawartości ferrytu na wytrzymałość na rozciąganie i wydłużenie przy zerwaniu wulkanizatów NR

tion at break (Fig. 8). At maximum ferrite loading there is spotted nearly 93% increase of observed property in comparison to the unfilled sample. The values of moduli were not possible to measure, because the vulcanizates were ruptured at deformation less than 100%.

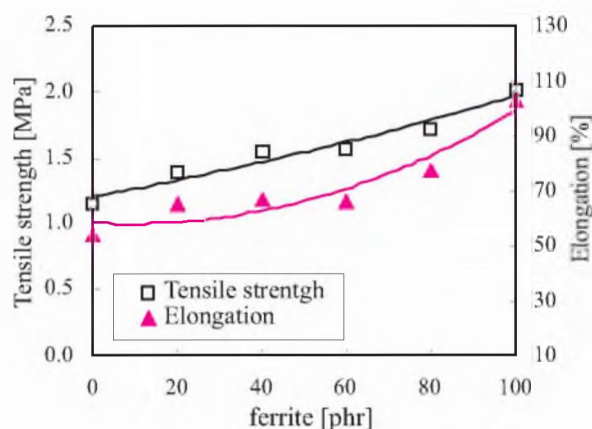


Figure 8. Influence of ferrite content on tensile strength at break and elongation at break of BR-vulcanizates  
Rysunek 8. Wpływ zawartości ferrytu na wytrzymałość na rozciąganie i wydłużenie przy zerwaniu wulkanizatów BR

The magnetic properties of both types of vulcanizates were evaluated at laboratory temperature and maximum coercivity of  $H_m = 750 \text{ kA} \cdot \text{m}^{-1}$ . The experimentally measured values of maximum magnetic flux  $\Phi_m$  and remanent magnetic flux  $\Phi_r$  increase markedly with increasing amount of ferrite in vulcanizates.

The maximum magnetic polarization  $J_m$  and the remanent magnetic polarization  $J_r$  were computed on the basis of experimentally determined  $\Phi_m$  and  $\Phi_r$  values using equations (4) and (5):

$$J_m = \frac{\Phi_m}{S} \cdot D \quad (4)$$

$$J_r = \frac{\Phi_r}{S} \cdot D \quad (5)$$

S – surface area of the sample, D – constant of the used apparatus TVM-1 (D = 16.4)

The maximum magnetic induction  $B_m$  and the remanent magnetic induction  $B_r$  were calculated utilizing equations (6) and (7):

$$B_m = \mu_0 \cdot H_m + J_m \quad (6)$$

$$B_r = \mu_0 \cdot H + J_r \Rightarrow B_r = J_r \quad (7)$$

$\mu_0$  – vacuum permeability

$H_m$  – maximum intensity of magnetic field ( $H_m = 750 \text{ kA} \cdot \text{m}^{-1}$ )

H – intensity of magnetic field ( $H = 0 \text{ kA} \cdot \text{m}^{-1}$ )

The remanent magnetic induction  $B_r$ , maximum magnetic induction  $B_m$  and maximum magnetic polarization  $J_m$  show significant increasing tendency with increasing of ferrite content in case of both NR as well as BR based vulcanizates (Fig. 9, 10). The difference between values  $B_r$  of BR-vulcanizates with 20 phr and

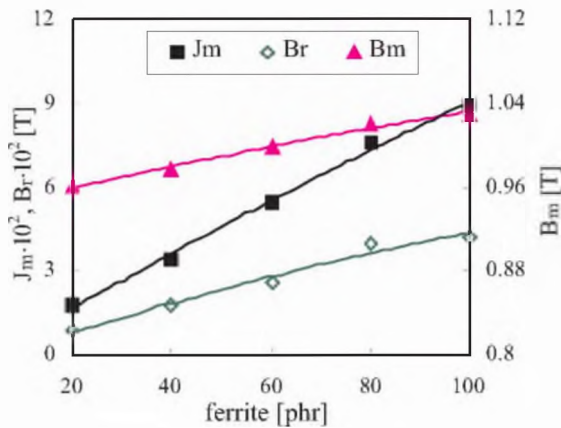


Figure 9. Influence of ferrite content on maximum  $B_m$ , remanent  $B_r$ , magnetic induction and maximum magnetic polarization  $J_m$  of NR-vulcanizates

Rysunek 9. Wpływ zawartości ferrytu na indukcję magnetyczną maksymalną  $B_m$ , indukcję magnetyczną szcztkową  $B_r$ , i maksimum polaryzacji magnetycznej  $J_m$  wulkanizatów NR

100 phr of ferrite was more than 180%. Sharp difference between the values  $B_r$  of sample with maximum ferrite loading and sample with minimum ferrite loading was recorded also in case of NR-vulcanizates, approximately 370%.

### 3.3. Influence of ferrite on cross-link structure of vulcanizates

There was also interesting to know whether ferrite could influence cross-link density a sulfur cross-link

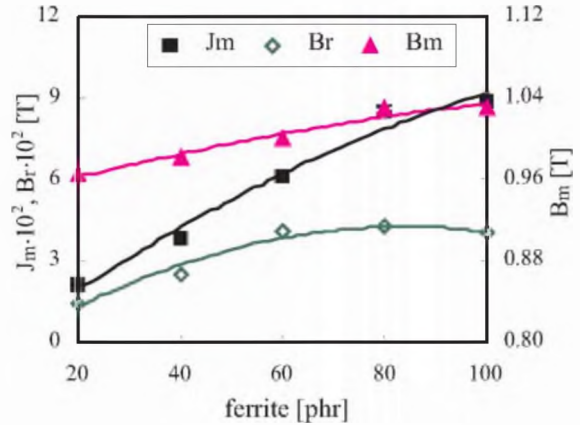


Figure 10. Influence of ferrite content on maximum  $B_m$ , remanent  $B_r$ , magnetic induction and maximum magnetic polarization  $J_m$  of BR-vulcanizates

Rysunek 10. Wpływ zawartości ferrytu na indukcje magnetyczną maksymalną  $B_m$ , indukcję magnetyczną szcztkową  $B_r$ , i maksimum polaryzacji magnetycznej  $J_m$  wulkanizatów BR

structure of vulcanizates. Therefore this effect was investigated. There was determined the total cross-link density  $\nu_t$  as well as the chemical cross-link density  $\nu_{ch}$ . The determination of both densities allowed the evaluation also the physical cross-links  $\nu_{ph}$  of prepared samples. Polymer-polymer physical interactions, polymer-filler physical interactions, also various intramolecular and intermolecular entanglements are involved in physical cross-link density.

As seen in Figure 11, the total cross-link density  $\nu_t$  and as well as the chemical cross-link density  $\nu_{ch}$  of ferrite filled NR-vulcanizates slightly increase with ferrite loading increasing. The physical cross-link density  $\nu_{ph}$ , which represents difference between total and chemical cross-link density ( $\nu_t - \nu_{ch}$ ), is much lower than  $\nu_{ch}$  and

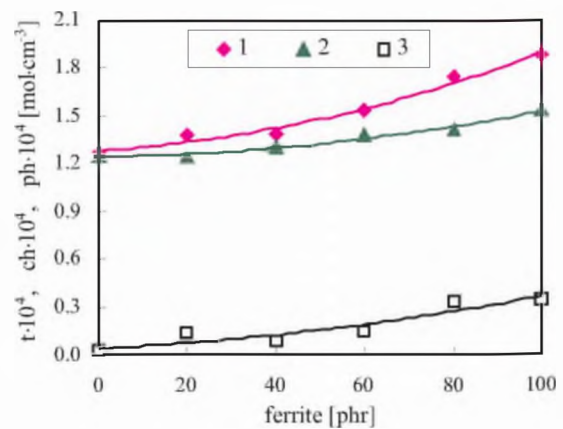


Figure 11. Influence of ferrite content on total  $\nu_t$  (1), chemical  $\nu_{ch}$  (2) and physical  $\nu_{ph}$  (3) cross-link density of NR-vulcanizates

Rysunek 11. Wpływ zawartości ferrytu na gęstość usieciowania wulkanizatów NR całkowitego  $\nu_t$  (1), natury chemicznej  $\nu_{ch}$  (2) i fizycznej  $\nu_{ph}$  (3)

increases non-linearly with increasing of ferrite content (Fig. 11).

Figure 12 illustrates the influence of magnetic filler content on cross-link densities of BR-vulcanizates. There is possible to see decline of  $v_{ch}$  values with increasing amount of ferrite, but the decrease of  $v_{ch}$  as a consequence of ferrite loading increasing from 0 to 100 phr does not exceed 15%. The results of measurements showed that the total cross-link density  $v_t$  of ferrite filled BR-vulcanizates seems to be independent on magnetic filler amount (Fig. 12).

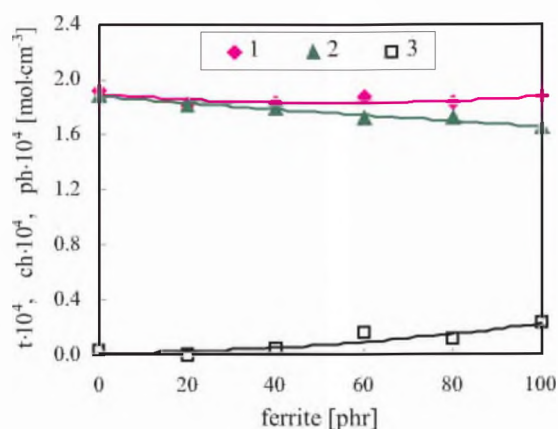


Figure 12. Influence of ferrite content on total  $v_t$  (1), chemical  $v_{ch}$  (2) and physical  $v_{ph}$  (3) cross-link density of BR-vulcanizates

Rysunek 12. Wpływ zawartości ferrytu na gęstość usieciowania wulkanizatów BR całkowitego  $v_t$  (1), natury chemicznej  $v_{ch}$  (2) i fizycznej  $v_{ph}$  (3)

To analyze cross-link structure, the thiol-amine method was used. There was utilized the ability of propane-2-thiol (2-PT) and hexane-1-thiol (1-HT) to decompose cross-links with various number of sulfur atoms in suitable reaction medium. The results show that by using 1-HT, the analyzed samples based on natural rubber were either completely decomposed or after drying they had powdery form. Simultaneously, there were released small particles of fillers from these samples and their weights were reduced. It is very probable that after disruption of polysulfidic and disulfidic cross-links (by using 1-HT) part of rubber macromolecules was released and dissolved. Therefore it might be assumed that the vulcanizates practically do not contain, or contain only a very few of monosulfidic cross-links. Polysulfidic cross-links were determined by 2-PT. From the chemical cross-link density ( $v_{ch}$ ) and cross-link density corresponding to polysulfidic cross-links ( $v_{Sx}$ ) the ratio of disulfidic cross-links in the networks of prepared vulcanizates ( $v_{S2}$ ) was computed. In case of NR-vulcanizates, the lowest  $v_{Sx}$  was obtained in unfilled vulcanizate (about 47% from  $v_{ch}$ ). With increasing of ferrite loading,  $v_{Sx}$  increases non-linearly up to 60% approximately (Fig. 13).

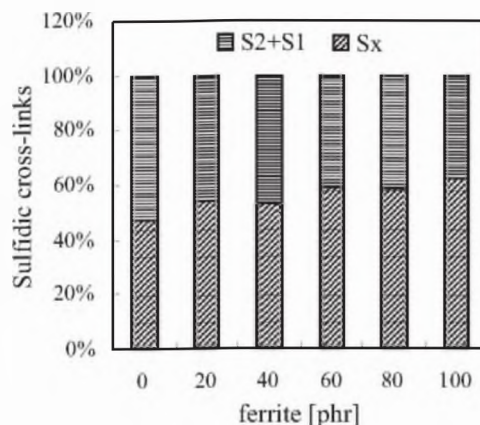


Figure 13. Influence of ferrite content on cross-link structure of NR-vulcanizates

Rysunek 13. Wpływ zawartości ferrytu na strukturę usieciowania wulkanizatów NR

From the Figure 14 is clearly seen that all types of sulfidic cross-links are present in cured rubber compounds based on butadiene rubber with dominance of polysulfidic cross-links. The content of  $v_{Sx}$  represents about 43-52% from  $v_{ch}$ , but the amount of magnetic

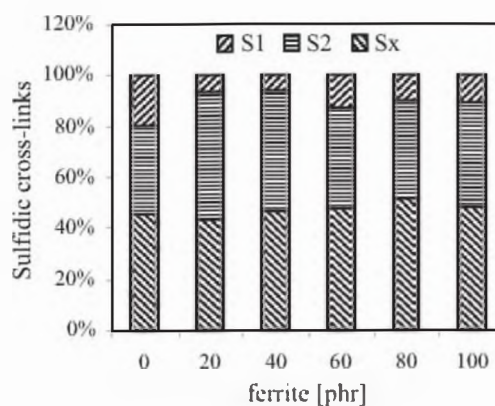


Figure 14. Influence of ferrite content on cross-link structure of BR-vulcanizates

Rysunek 14. Wpływ zawartości ferrytu na strukturę usieciowania wulkanizatów BR

filler has no significant influence on their values. The content of disulfidic and monosulfidic cross-links represents about 35-50% or 7-20% from  $v_{ch}$  of BR-vulcanizates, but the content of  $v_{S2}$  and  $v_{S1}$  seem also to be independent on the magnetic filler loading.

## 4. Conclusion

The work was aimed at the study of magnetic filler influence on curing process, properties and cross-linking of model compounds based on natural as well as butadiene rubber. The results of measurements showed, that the incorporation of ferrite in rubber compounds

leads to acceleration of sulfur curing process. The presence of ferrite in NR-vulcanizates causes the increase of moduli predominantly, which increase considerably with increasing of ferrite content in vulcanizates. The influence on tensile strength was insignificant. The elongation at break, by contrast, exhibits the decreasing tendency with increasing of magnetic filler content. The physical-mechanical properties of BR-vulcanizates, the tensile strength at break and the elongation at break, were found to increase with increasing of ferrite content in rubber compounds. The values of moduli were not possible to measure, because the BR-vulcanizates were ruptured at deformation less than 100%. All evaluated magnetic characteristics of BR-vulcanizates as well as NR-vulcanizates exhibit significant increasing tendency with increasing of magnetic filler content. In the network structure of both types of vulcanizates chemical cross-links dominate over physical ones. Monosulfidic cross-links were not found experimentally in case of vulcanizates based on natural rubber. The cross-link structure of NR as well as BR-vulcanizates is formed from polysulfidic and disulfidic cross-links especially. The cross-link structure of vulcanizates depends slightly on magnetic filler content.

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## References

1. Soloman M.A., Kurian P., Anatharaman M.R., Joy P.A., *Polymer Plastics Technology and Engineering* 2004, **43**, 1013-1028.
2. Farshad M., Benine A., *Polymer Testing* 2004, **23**, 347-353.
3. Paul K.B., *Physica B*, 2007, **388**, 337-343.
4. Bellušova D., Alshuth T., Schuster R.H., Myndyk M., Šepelak V., Hudec I., *Kautsch. Gummi Kunstst.* 2008, **61**, 118-123.
5. Kruželák J., Szabová R., Bellušová D., Kyselá G., Hudec I., *Kautsch. Gummi Kunstst.* 2010, **63**, 20-24.
6. Goldman A., *Modern Ferrite Technology*, Van Nostrand Reinhold, New York, 1990.
7. Malini K. A., Mohammed E. M., Sindhu, S., Joy, P.A., Date, S. K., Kulkarni, S.D., Kurian P., Anantharaman M.R., *Journal of Material Science* 2001, **36**, 5551-5557.
8. Gutfleish O., *Encyclopedia of Materials, Science and Technology*, Elsevier Science Ltd, 2001.
9. Dinzberg B.N., *Kautsch. Gummi Kunstst.* 1999, **52**, 413-419.
10. Saville B., Watson A.A., *Rubber Chem. Technol.* 1967, **40**, 100.
11. Morrison N.J., Porter, M., *Rubber Chem. Technol.* 1984, **57**, 63-85.
12. Warner W.C., *Rubber Chem. Technol.* 1994, **67**, 559-566.

## „Poradnik Technologa Gumy”

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