

ONLINE ELECTRICAL CONDUCTIVITY – A METHOD FOR MONITORING AND CHARACTERIZING THE MIXING PROCESS OF CARBON BLACK FILLED RUBBER COMPOUNDS

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1. INTRODUCTION

The mixing of carbon black in rubber vulcanizates improves their performance-related properties¹⁻⁵. However, to obtain optimum vulcanizate properties the carbon black must be sufficiently dispersed in the mixture⁶. Poor dispersion can in itself give rise to certain detrimental effects. Agglomerates with domain size larger than 6 μm that can act as failure-initiating flaws, are responsible for the decrease in ultimate tensile strength, breaking and tearing energy, fatigue resistance, etc. The influences of such as agglomerates are quantified by the so-called macro-dispersion. Small agglomerates and aggregates (micro-dispersion) influence the end use performance of many vehicle systems. The improved micro-dispersion resulted in lower hysteresis properties and higher resistance to tearing, cut growth and abrasion⁴.

To get an optimal CB dispersion a knowledge about mixing processes and influencing factors is essential. In general, the dispersion rate has been governed by the filler-filler and filler-polymer interaction^{7, 8}, the type of filler^{9, 10}, the technological^{11, 12} and rheological parameters as well as the order of mixing and the addition of process oil¹³⁻¹⁶.

In a larger number of cases carbon black filled rubber blends are prepared in order to obtain a good combination of application properties at a high level. An essential factor influencing the mechanical performance of CB filled rubber blends is the phase selective CB distribution. A lot of work has been done to characterize the CB distribution and the mechanical properties of the CB filled blends in the vulcanized state¹⁷⁻²². However, the available methods for characterization of CB distribution are very time consuming. The results are inconsistent and the kinetics of CB dispersion during the mixing process of blends has been investigated insufficiently.

In mixing process, due to the process fluctuation it leads to irregularity, that causes the quality losses or even the uselessness of the mixture. Production waste has been a load for the ecological system and a waste of raw materials and energy. Up to now, the mixing process has been regulated by a given time and/or temperature and/or energy development²³. In such way the technological parameters used deliver only restricted information about the actual characteristics of the current rubber mixture. For example the temperature development in the rubber mixture can be affected by the energetic state of the mixer or by the dose fluctuation or variations of the raw material characteristics. The same happens to the energy and torque progress. It would be desirable to develop a simple way to monitor the production. Lately the RELMA method (remote lasers Micro analysis)²⁴ and the ultrasonic method²⁵ were presented. They give information about the relative concentration of the filler and its distribution in the macroscopic scale directly after mixing and thus very fast about the quality of rubber mixture. However these methods can be only used in extruder, and they are not able to supply information about the morphology development of the mixture. Theoretical^{26, 27} and experimental^{4, 28} methods were presented to describe the carbon black dispersion in rubber compounds. Among them the methods using electrical conductivity of carbon black deliver consistent results and need only a short time^{29, 30}. Depending on carbon black concentration and grade the number of connections between carbon black aggregates is different resulting in various levels of conductivity. After passing a certain carbon black concentration called percolation threshold the conductivity increases significantly (several order of magnitude)³¹. At this concentration carbon black aggregates are able to form a continuous conducting network through the rubber matrix. However, the electrical conductivity depends not only on the concentration but also on the dispersion of carbon black^{32, 33}. Keeping constant the CB concentration the conductivity is related to the CB dispersion state. From the idea that the electrical conductivity can be measured directly from the internal mixer during the mixing process, one tried to use it as a measure to monitor the mixing process and degree of dispersion already for a longer time³⁴. Intensive investigation has been made in this field by Friedle-Haarde³⁵ and Oppermann³⁶ but they used an insufficient equipment construction, which was not able to deliver a consistent curve, and an available method has lacked to evaluate the electrical conductivity curves.

In the last two years in collaboration with Thermo Electron we modified a laboratory chamber equipped with a conductivity measurement device for carbon black filled rubber mixtures^{37, 38}. Thanks to the optimal construction of the measuring equipment it is possible to receive good reproducible curves of conductiv-

ity. The aim of our project is to develop an online method for the characterization of the mixing process of CB filled rubber compounds and rubber blends using the online electrical conductivity measured directly from the internal mixer. The experimental results were published in some articles³⁹⁻⁴⁶ and will be briefly summarized in this report.

2. METHOD

Figure 1 shows the installation of a conductivity sensor in a mixer chamber. Instead of a thermocouple, a conductivity sensor with integrated thermocouple was installed in the saddle of the mixer as described in our previous³⁷.

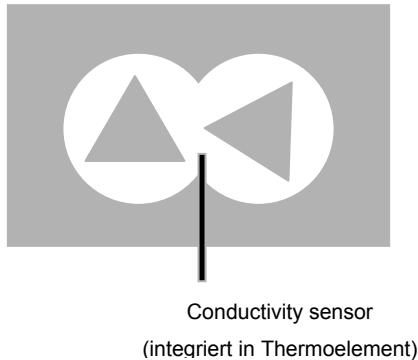


Fig. 1 - Installation of a conductivity sensor in an internal mixer

The chamber wall acted as the second electrode. For all the mixtures investigated, a measuring range of the conductivity from 0 mS to 200 mS was chosen. The factor K thereby is a quantity of the online conductivity C_{On} corresponding to equation 1.

$$C_{On} = K \times \sigma_{max} \quad (1)$$

σ_{max} is the maximum of the measuring range; in this case σ_{max} is equal to 200 mS.

The optical microscopy has been used to characterize the CB dispersion. This method was described by Stumpe and Railsback⁴⁷ and modified by us. In our case the dispersion degree is related to the amount of the non-dispersed agglomerates with an average diameter greater than 6 μ m. After microscopic visualization image analysis was used to quantify the dispersion degree of CB according to ASTM 2663⁴⁸.

3. RESULTS AND DISCUSSION

3.1 Correlation between the online conductivity and carbon black dispersion

Inspecting the conductivity and carbon black dispersion curves of all samples investigated a corresponding change in all of them has been observed. As an example, the factor K of the online electrical conductivity and CB dispersion of the gum NR is presented in figure 2⁴².

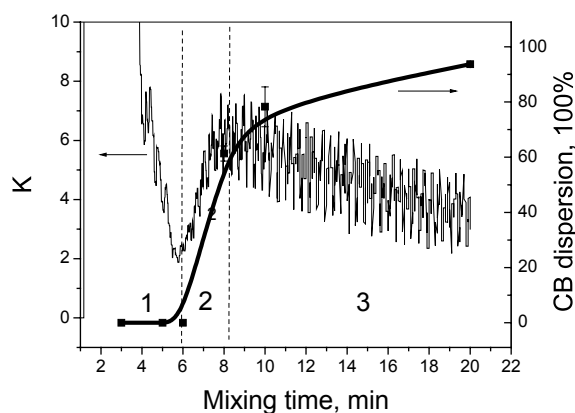


Fig. 2 - Relation between online conductivity and carbon black dispersion values

The conductivity and dispersion show three distinct stages. In the stage 1, the sensor is surrounded by the free carbon black which causes a short circuit showing a very high electrical conductivity. With progressive encapsulation of carbon black through the rubber matrix, the fraction of the free carbon black continuously decreases until a clear decrease in the conductivity is observed. In this stage, the CB dispersion shows a value near to zero. After passing a minimal value, the conductivity of the mixture increases again and reaches a local maximum as observed in the stage 2. At the same time the values of the CB dispersion sharply increase. The change of the conductivity and CB dispersion are determined by a very complex behavior of the mass in the mixing chamber. Three main processes can take place

simultaneously in this stage: the infiltration of the rubber chains into the voids within the CB agglomerates, the detachment of fine particles on the periphery of the agglomerates (dispersion process), and the distribution of the fine particles throughout the rubber matrix. On the basis of the discussion made by

Medalia⁴⁹ and Manas-Zloczower^{50, 51} about the correlation between the infiltrated rubber layer and the force transfer from rubber matrix to the CB agglomerates as well as the “onion model” proposed by Shiga and Furuta³² we try to explain the increase of the conductivity and its correlation to the value of the CB dispersion in the stage 2. Medalia postulated, that due to the occluded rubber the effective volume is greater than the solid volume. As an aggregate is nodular, the solid volume is the volume of a sphere, which occupies the same space as the aggregate. The effective volume is the sum of the solid volume and the occluded rubber. The occluded rubber is the volume fraction of rubber infiltrated into the voids of carbon black agglomerates. Infiltrated rubber is now considered as being a part of the filler, and the volume of the free rubber becomes less. Hence, the effective volume of carbon black increases with the infiltration resulting in an increasing contribution of the online conductivity (figure 3a). Manas-Zloczower emphasized the important role of an infiltrated rubber layer for the CB dispersion process. Thanks to the infiltrated rubber layer the hydrodynamic stress can be distributed throughout the whole infiltrated region and can act to remove fragments from the surface of the agglomerate in sizes up to the infiltration depth. Thus, the values of CB dispersion increase in this stage simultaneously with the infiltration process. The fine particles - small aggregates - detached can build a “cloud” surrounding the agglomerates as illustrated in figure 3b.

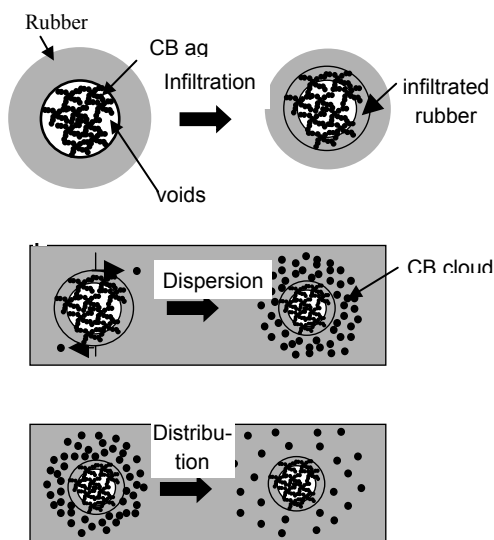


Fig 3. - Schemes illustrating the infiltration (a), dispersion (b) and distribution process (c) in a filled rubber compound

This cloud-particles are not detectable by the optical microscopy but they enlarge the conductive area of the CB agglomerates. According to the “onion model” proposed by Shiga and Furuta³² the clouds surrounding different agglomerates can touch each other and build a network, that leads to an increasing contribution of the conductivity. Furthermore, due to the shear force and the mass transfer the fine particles are distributed throughout the rubber matrix (figure 3c). The network is destroyed that causes a decreasing contribution of the online conductivity. As a result, the increase of the conductivity in the stage 2 results from the domination of the increasing contributions caused by the rubber infiltration and CB dispersion processes towards the decreasing contribution made by the CB distribution process. This domination decreases with the mixing time, and when it approaches towards zero the conductivity reaches the maximum. The mixing time corresponding to the maximum conductivity is called BIT (Black Incorporation Time). At this time the infiltration process seems to be completed. Beyond the BIT, in the stage 3, the CB dispersion rate progressively reduces, while the small aggregates are intensively distributed. The pronounced decay of the conductivity is mainly caused by the better

distribution process of the small aggregates throughout the rubber matrix and therefore the increasing distances between the aggregates.

3.2. Effect of material parameters

The effects of material parameters like molecular weight, molecular structure, polarity, branching grade or addition of oil on the online conductivity curve and macro-dispersion values were intensively characterized⁴¹⁻⁴³.

As an example, figures 4a and 4b show the conductivity and dispersion curves of natural rubber designed as N1, N2 and N3 with different molecular weight ($N1 > N2 > N3$), respectively. Hence, the shear stress decreases in the range from the sample N1 to N2 and N3. The filler-polymer interaction of three samples is thought to be the same when mixing with carbon black. With decreasing matrix viscosity, the BIT shifts to a shorter mixing time. This is related to the fact that due to the low viscosity the rubber chains easily infiltrate into the carbon black.

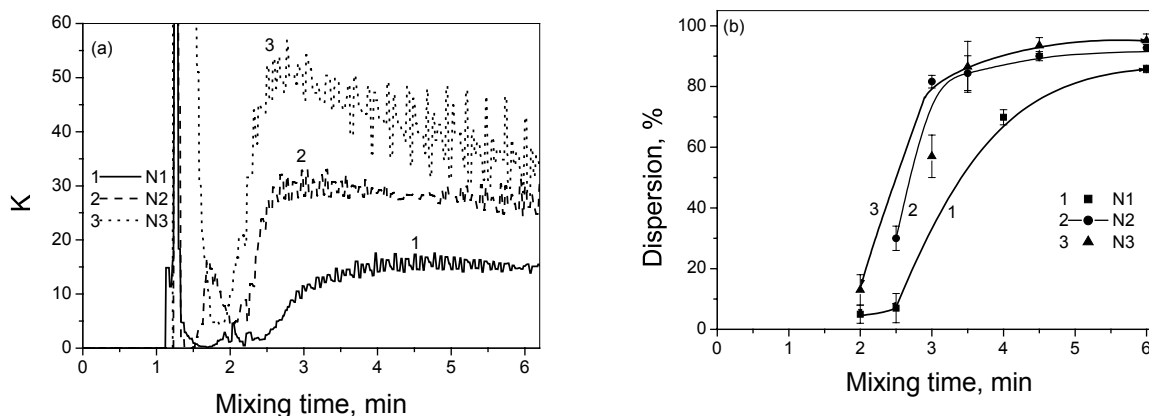


Fig. 4 - Online electrical conductivity and carbon black dispersion values in dependence on the molecular weight of the rubber matrix and mixing time

In figure 4b, the CB dispersion of the three samples N1, N2 and N3 is presented depending on the mixing time. The sample N1 shows the slowest development of dispersion. Up to the mixing time of 2.5 min the dispersion determined is only 5 %. Inspecting the corresponding conductivity curve, at this period the rubber chains of the sample N1 does not infiltrate in the carbon black yet. Although the shear stress of the sample N1 is high but the stress distribution is uneven due to the absence of the infiltrated rubber layer. After the mixing time of 2.5 min, the conductivity value increases as a result of the infiltration process. The extend of filler dispersion also increases as seen from figure 4b. Thanks to the fast infiltration process the samples N2 and N3 show a faster increase of the dispersion values than the sample N1.

The effect of the rubber polarity of the three rubbers NR, SBR and NBR on the conductivity was investigated^{41, 42}. Due to the presence of the functional groups, acrylonitrile butadiene rubber (NBR) and styrene butadiene rubber (SBR) show a stronger interaction with carbon black than the non-polar rubber NR. The high polarity of NBR accelerates a strong interaction with carbon black surface which intensifies the infiltration process. With increasing polarity the BIT shifts to shorter times. Due to the fast infiltration process and the good polymer-filler interaction, the carbon black dispersion value of NBR increases very fast. In spite of the lower viscosity, the BIT of the non-polar NR is longest and the infiltration process takes place slowest. It leads to the slower development of the carbon black dispersion value. From this result it is obvious that the matrix polarity and viscosity oppositely affect the infiltration process. However, the former is more effective than the later.

To characterize the effect of branching degree of the rubber on the online electrical conductivity and carbon black dispersion, the behavior of the linear S-SBR and the branched E-SBR was compared⁴³. The BIT of S-SBR is significantly shorter than that of E-SBR. That means, S-SBR shows a higher infiltration rate than E-SBR. This behavior can be explained by taking into account the chain structure of both rubbers. S-SBR has a linear chain structure while E-SBR has a branched one. Basically, the complexity of the chain structure slows down the infiltration rate of a rubber into the carbon black agglomerates. Thus, the linear chains of S-SBR can easily infiltrate into carbon black, what is responsible for the shorter BIT in comparison to E-SBR. In correlation with the shorter infiltration process, the macro-dispersion of S-SBR increases already at a shorter mixing time. E-SBR shows a slower development of the carbon black dispersion.

The addition of process oil into rubber causes a change of viscosity of material and filler-polymer interaction as well as shear stress and mass temperature. As a result the CB dispersion development changes correspondingly. By investigating the shift of the BIT and the values of the online conductivity measured at the BIT, the effect of content and polarity of the process oils on the CB dispersion in rubber compound of different polarity was clearly characterized⁴¹.

3.3. Effect of technological factors

Basing on the experimental results the online measured electrical conductivity is affected by technological factors (mixing time, chamber wall temperature, filling grade, rotor speed, geometry of rotor)³⁸⁻⁴⁰.

In figure 5a the normalized conductivity factor K/K_{BIT} of the three mixtures prepared by different rotor speed is presented⁴⁰. By decreasing rotor speed the conductivity curve is shifted to longer mixing times. In spite of the change of mass temperature and shear stress, figure 5b shows the CB dispersion developing in the same order like the conductivity values.

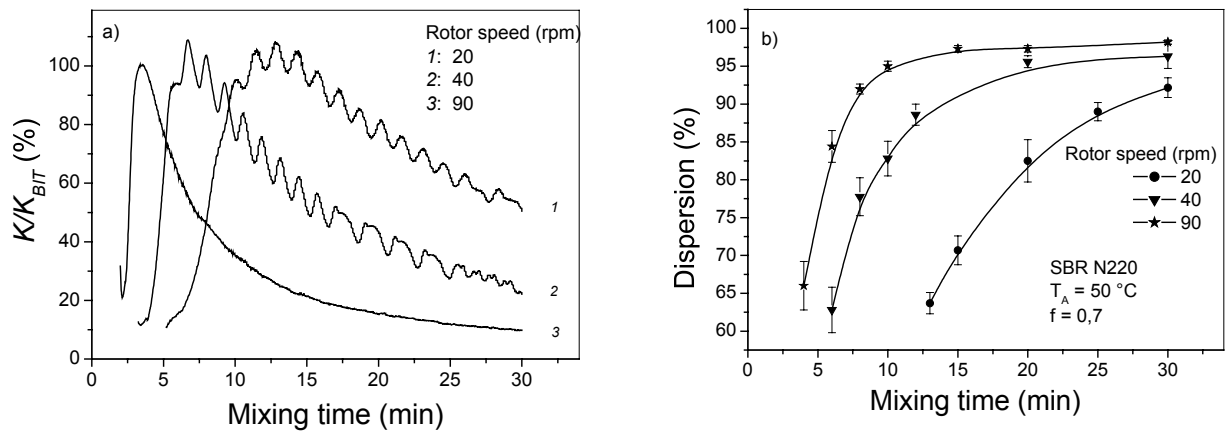


Fig. 5 - normalized conductivity factor K/K_{BIT} (a) and carbon black dispersion (b) in dependence on rotor speed

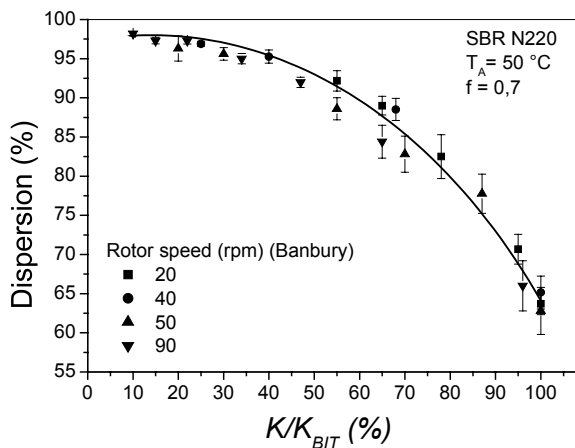


Fig. 6 - Master curve of carbon black dispersion vs. normalized conductivity factor K/K_{BIT} measured at different mixing parameters

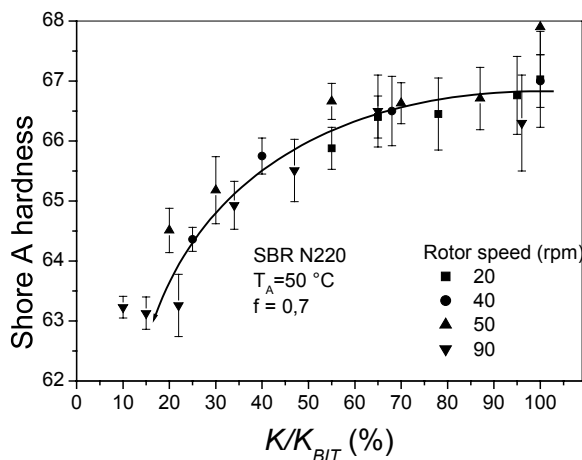


Fig. 7 - Master curve of hardness vs. normalized conductivity factor K/K_{BIT} measured at different mixing parameters

Basing on the experimental results reported above a qualitative correlation between normalized conductivity factor K/K_{BIT} and carbon black dispersion is observed. To quantify this behavior carbon black dispersion obtained by different mixing parameters is plotted vs. the normalized conductivity factor as shown in figure 6. For the investigated system the dispersion index increases with the decreasing normalized conductivity factor K/K_{BIT} . This behavior does not depend on the mixing parameters and can be described by an unique master curve. That means the mixture possessing the same normalized conductivity factor K/K_{BIT} delivers the same carbon black dispersion independent of mixing parameters. Thus, it is possible to use normalized conductivity to monitor the development of carbon black dispersion during mixing process.

The dispersion determined by the optical method is more or less dependent on a subjective factor. Using mechanical methods like tensile test, hardness measurement and dynamic-mechanical analysis more objective information about carbon black dispersion can be determined.

In figure 7 hardness of mixtures prepared at different mixing parameters are presented in dependence on the normalized conductivity factor K/K_{BIT} . Hardness and its standard deviation decrease with decreasing conductivity, which indicates a better dispersion of carbon black. In the frame of the experimental error the mechanical and chemical testing confirm the former results (shown in figure 6) that the mixtures possessing the same normalized conductivity factor K/K_{BIT} deliver the same carbon black dispersion and the same mechanical properties.

3.4. CB dispersion and distribution in rubber blends

In figure 8a the conductivity of SBR, NR and their 50/50 blend is represented in dependence on the mixing time. SBR and NR show the similar shape of the conductivity curves, but the curve of NR is shifted to longer mixing times. As SBR reaches the maximum of the conductivity (BIT) at a mixing time of about 7 min, NR still remains non-conductive. Just after a mixing time of 12 min, the BIT of NR is observed. That is related to the slower infiltration process of NR, which is caused by the lower chemical affinity of the NR chains to the CB surface in comparison to SBR. The shift of the conductivity curve of NR causes the shift of its dispersion curve shown in figure 8b.

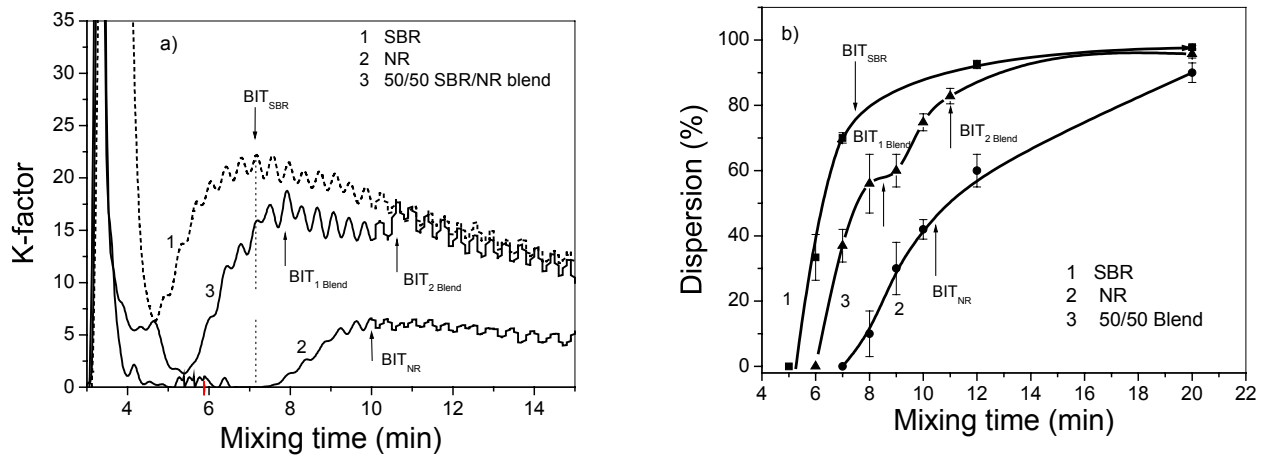


Fig. 8 - Online conductivity (a) and CB dispersion (b) of EPDM, NR and their 50/50 blend

The CB filled 50/50 SBR/NR blend presents a conductivity curve with two BITs, which are obviously related to the blend components. The analysis of this curve can give a consistent description of the mixing process and the development of CB dispersion in filled rubber blends. The probability, that CB gets in contact with both blend components in the initial mixing step is the same. Due to a higher infiltration rate of SBR, CB is fast infiltrated by the SBR component. As a result, the first BIT in the conductivity curve is related to the dispersion of CB in the SBR component. After a certain mixing time, the NR component begins to infiltrate the CB too. This process is the reason for the appearance of the second BIT. Due to the sequential infiltration processes of each blend component, the dispersion process starts to run at first in the SBR phase and then in the NR phase, that is clearly shown in figure 8b. The dispersion curve of the blend presents two plateaus at mixing times corresponding to the BITs of the blend components. It is interesting to notice that the BITs of the two blend components shift to longer mixing times in comparison to the BITs of the corresponding single mixtures. The shift of the BIT is obviously related to the fact, that the CB infiltration process of a rubber blend component is inhibited at the presence of its blend partner.

Looking at the conductivity curves of CB filled SBR and NR single mixtures presented in figure 8a makes clear, that at the mixing time of 7 min SBR reaches the BIT, while NR is still non-conductive. From this

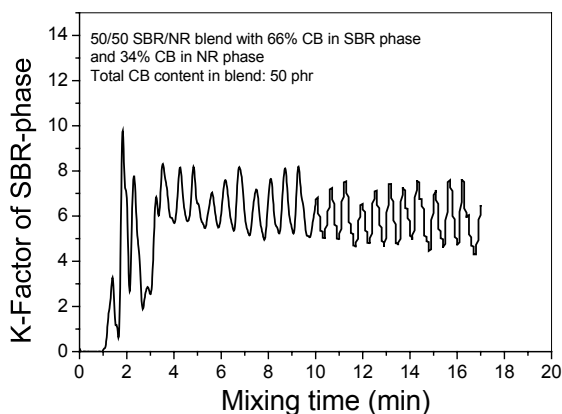


Fig. 9 - Value of conductivity measured by preparing blends from masterbatches with definite CB distribution

result we can conclude that in the case of a blend the conductivity value measured at the first BIT in the blend is caused by a definite CB content distributed in the SBR phase. The correlation between the value of conductivity measured at the BIT of the SBR phase and its CB distribution can be used for the estimation of CB distribution in rubber blends. To create such a correlation, we prepared blends from masterbatches with definite CB distribution. To produce those masterbatches, single SBR and NR rubber mixtures were separately mixed with the corresponding CB content. At a certain mixing time, when the filled SBR reaches the BIT and NR is still non-conductive, the mixing process was stopped. After this, the two masterbatches were mixed together. The volume of the masterbatches for

preparing blends was calculated carefully in order to keep constant the blend ratio always at 50/50 and the total CB content in the blends at 50 phr. Using this mixing procedure, it was possible to prepare 50/50 SBR/NR blends with well-known CB content distributed in both phases.

As an example, by preparing the blends from masterbatches with a CB percentage of 66 % distributed in the SBR phase and 34 % in the NR phase, the online conductivity was measured as shown in figure 6. Up to a mixing time of 3 min, the conductivity does not show a constant value because of the change of blend morphology and mass temperature in this mixing step. When the blend morphology and the mass temperature does not change any more the conductivity reaches a plateau. As mentioned above, this value of conductivity is caused only by the SBR phase measured at the BIT.

The correlation between the conductivity value of the SBR phase measured by preparing definite blends from masterbatches and the CB percentage distributed in SBR phase of those blends is presented in figure 10. Up to a CB percentage of 50 % the dependence of conductivity on the CB content corresponds to the percolation concept. It is interesting to observe, that by further increasing of the CB content in the SBR phase the conductivity reaches a maximum and then decays strongly. Relating to the morphological investigation in recent work⁴⁶, the 50/50 SBR/NR blend with CB content up to 40 phr shows a morphology

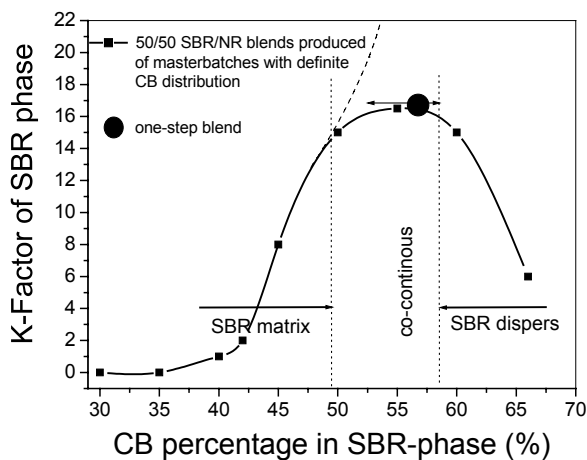


Fig 10 - Correlation between conductivity values and CB percentage distributed in the SBR-phase of the SBR/NR mixtures

of NR domains dispersed in a SBR matrix. The results in the present work let us presume that the increase of CB content in the SBR phase changes the viscosity ratio between the blend phases, which can lead to a morphology inversion as schematically displayed in figure 10. If a morphology inversion takes place, the SBR matrix inverts into SBR domains. The non-conductive NR matrix prevents contact between conductive SBR domains, which leads to a decrease of the conductivity of the blend.

Comparing the conductivity values measured at the first BIT of the 50/50 SBR/NR blend (see the conductivity curve in figure 2a), which is prepared in a one-step mixing process without the production of masterbatches, with the conductivity values presented in figure 10, it is possible to estimate the CB percentage distributed in the SBR of the one-step blend. The conductivity value of the SBR phase in the one-step blend is marked as a large full circle

corresponding to a CB percentage of about 57 % in the SBR phase. This result is in agreement with the CB distribution in the SBR-phase determined using the TGA method, like it was shown in our recent work⁴⁶

3.5. Effect of CB type and CB mixture

Although the online electrical conductivity measurement method presents a powerful tool for characterization of the mixing process of CB filled rubber compounds, its use is only on condition that the integrated sensor must be able to measure the electrical response from the filled rubber compound. In order to receive the electrical response the CB content must be above the percolation threshold. As a background for the conductive nature of CB the primary particle size and structure of carbon black which are the most influencing parameters are briefly considered^{52, 53}. Regarding to the specific surface area and the structure, some CB types do not show any electrical response during the mixing process in spite of very high loading. For example, N772 and N990 behave as a non-conductive filler at loading of 110 phr. In contrast, EC300 shows a strong electrical response at loading of 15 phr. As a disadvantage, the mixing process of such a non-conductive CB could not be characterized by use of the online electrical measurement method.

Figure 11a shows the online measured conductivity of rubber compounds filled with EC300, N220 and N772 in dependence on the mixing time. EC300 and N220 present a characteristic chart of conductivity as observed in our previous works. The value of the BIT of N220 is shorter than the one of EC300. That means, N220 shows a higher infiltration rate than the EC300. In contrast, N772 shows the first peak of conductivity which is due to the short-circuit when CB connecting two electrodes by adding. Further, no electrical response was observed in spite of a high CB loading.

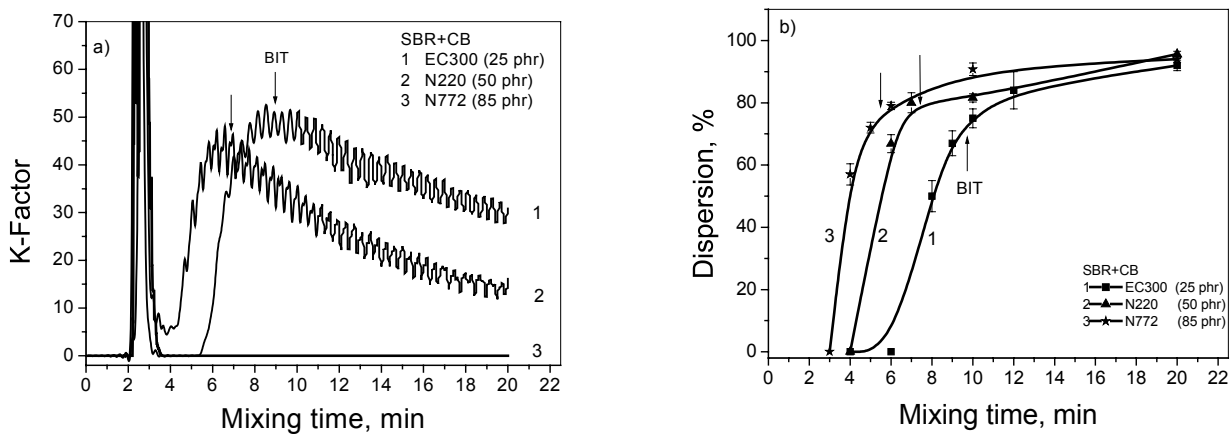


Fig. 11 - Online conductivity and CB dispersion of different CB types

Figure 11b shows the change of the dispersion value of EC300, N220 and N772 with the mixing time. Due to the fast infiltration process observed from figure 10a, the value of the CB dispersion of N220 increases already at the shorter mixing time, whereas EC300 shows a slower development of the CB dispersion. It is worth to notice that the correlation between the online measured electrical conductivity and the CB dispersion which was repeatedly observed in different rubber compounds filled with N220 is true for different CB type like EC300 too. In comparison to EC300 and N220, N772 needs the shortest mixing time to receive high dispersion level. However, the development of CB dispersion of N772 could not be monitored during the mixture preparation because of the lack of the online measured conductivity.

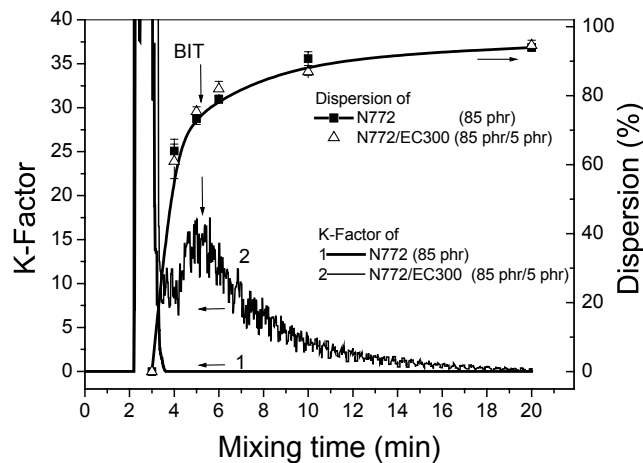


Fig. 12 - Online conductivity and CB dispersion of rubber compound filled with N772/EC300

makes SBR-N772/EC300 conductive and it does not affect the dispersion of N772. The BIT of SBR-N772/EC300 accords with the intercept of dispersion curve.

4. CONCLUSIONS

Different factors on the online conductivity and CB dispersion in filled rubber compounds and blends was systematically investigated. According to the experimental results the online electrical conductivity presents a powerful tool for the characterization of the mixing process of carbon black filled rubber compound in the laboratory scale. It provides a deep insight into the mixing processes of the rubber during the mixing.

To make use the online electrical measurement method for the CB filled rubber compounds at the CB loading below the percolation threshold, a possibility we would propose in the present work is an addition of a small amount of a high-conductive CB type as an indicator into the non-conductive CB filled rubber compounds. Thank to this indicator the filled rubber compound becomes conductive and the integrated sensor can measure some electrical responses which can give information about the mixing process. In figure 12 the online conductivity and the CB dispersion of SBR-N772 and SBR-N772/EC300 are presented with the mixing time. Both SBR-N772 and SBR-N772/EC300 present the same development of CB dispersion. While SBR-N772 does not show any conductivity except the first peak at 3 min, a small amount of EC300

The influence of viscosity, polarity as well as molecular structure of the rubber matrix, and the types and contents of extender oil on the carbon black dispersion has been characterized using the method of the online electrical conductivity measurement. A corresponding change of the online conductivity with the rubber infiltration and an extent of carbon black dispersion has been observed. The infiltration rate increases with increasing polarity and decreasing viscosity of the rubber matrix. However, the matrix polarity shows a stronger effect than the viscosity. A linear chain structure as well as a low molecular weight of the matrix rubber accelerate the infiltration process and hence the carbon black dispersion process takes place faster. A lower chain mobility caused by a modification of the rubber with functional groups leads to a deceleration of the CB infiltration. The oil addition influences the infiltration process by changing the matrix viscosity and the filler-matrix interaction as well as the shear stress. The oil addition affects the carbon black dispersion in non-polar rubber much more than in polar rubber. Furthermore, in non-polar rubber polar oil shows a stronger effect than non-polar oil.

The online measured conductivity of a rubber-carbon black mixture is influenced not only by the carbon black dispersion but also by the mixing parameters like mixing time, chamber wall temperature, rotor speed and rotor geometry. Through normalization of the conductivity with regard to the conductivity measured at BIT a normalized conductivity curve is received that does not depend on the mixing parameters any more. The rubber compound possessing the same normalized conductivity factor K/K_{BIT} delivers the same carbon black dispersion and the same mechanical properties. Thus, the normalized conductivity could be used as a measure for monitoring the mixing process. Basing on the online conductivity the kinetic of mixing processes has been discussed to find an optimal mixing regime.

The kinetics of CB dispersion in the SBR/NR and EPDM/NR blends has been investigated using the online measured electrical conductivity. Analyzing the conductivity curves, it could be shown that the infiltration and dispersion processes take place sequentially in the blend phases. A delay of the Black Incorporation Time (BIT) measured in the blend phases in comparison to the BIT of the corresponding single rubber occurs. This effect is explained by rheological and thermodynamic reasons taking into consideration also morphological effects. Using the online conductivity measurement method the selective CB distribution in the blend phases can be estimated.

The effect of the ratio of CB mixture on the online conductivity was investigated. Regarding to the structure and specific surface area different CB types show different critical CB content, below this the CB filled rubber compound is non-conductive. The BIT is strongly dependent on the structure and specific area of CB. By addition of a small amount of a high-conductive CB type into the non-conductive CB filled rubber compound, a characteristic online conductivity curve is observed which can be used to monitor the CB dispersion process of the non-conductive rubber compounds.

The online electrical conductivity shows not only advantages for characterization of the mixing mechanisms in the laboratory scale but also promises an potential tool for monitoring the production of rubber compounds. The results for the test in larger mixer will be published in the nearest future.

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