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„Rubber aging phenomena“

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Organisation Committee:

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Petra Svěráková (Centre of Polymer Systems)
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Preamble

The technical rubber is a cross-linked polymer system, which has unique viscoelastic behaviour, because of them this system has broad application in the industry as conveyor belts, transmission belts, shock absorbers, tires, hoses etc. These unique elastic and viscoelastic behaviour set very high requirement on the material in the practice, which are caused due to complex loading conditions. In service, rubber products are subjected to highly dynamic loading as well as are exposed to physical processes caused due temperature fluctuation, ozone concentration, etc. These extreme requirements have a significant effect on the fatigue and failure of product and lead to the degradation of the mechanical properties of rubber matrix. The initiation of local instability in tire due to fatigue is particularly caused by the nucleation of micro-crack. Its propagation may cause dangerous consequences because of the catastrophic failure of product leading to fatal accidents. Hence the understanding of the crack initiation and its propagation in rubber with respect to the applied varied physical processes as well as loading conditions is a subject of high scientific interest.

Rubber components are very much subjected to thermal aging due to internal heat generation because of viscoelastic losses during dynamic loading. The description of the mechanical behaviour of rubber product in the field under the influence of the thermos-mechanical processes need advanced methodology as well as testing equipment. The testing in the field are very time and money consuming, whereas the results are based only on the given type or dimension of analysed product. Thus it is necessary to locate the tests in to the laboratory and use small test specimens to simulate the real loading conditions applied on product. The data evaluated in the laboratory precisely describe the mechanical behaviour of rubber matrix based on compounds used for rubber application, under the thermos-mechanical aging. This data create the fundamental database to be used in the predicative simulation method based on Finite Element Method for model determination describing the mechanical behaviour of rubber matrix. Such model can be applied for simulation of mechanical behaviour under fatigue loading conditions and influenced by thermos-mechanical aging of rubber product in the real usage.

Centre of polymer systems at the Tomas Bata University in Zlin started the work the scientific topic focussed on aging of rubber within the joint Czech-Bavarian research project reg. no. 8E15B007- with the topic „Experimental investigation on rubbers' mechanical behaviour under fatigue loading conditions including chemo-thermomechanical ageing " within the Programme Joint Call of the Bavarian State Ministry of Education, Science and the Arts and the Ministry of Education, Youth and Sports of the Czech Republic for joint projects 2016-2017. The Bavarian cooperation partner is Univ.-Prof. Dr.-Ing. habil. Alexander Lion, Head of the Institute of Mechanics of the Universität der Bundeswehr München.

The main aim of the project was to improve a research cooperation between the both of researching partners, whereas the scientific aim of the project is to describe the quasi-static as well as dynamic behaviour of rubber material affected with the chemo-thermomechanical ageing and to contribute to numerical modelling for describing of the aging mechanism.

This seminar proceeding collects the most important works focussed on aging of rubber, which were done within this joint Czech-Bavarian research project as well as servers an overview of additional work done on this topic as current state of the art.

We highly appreciate and acknowledge the Ministry of Education, Youth and Sports of the Czech Republic to support us at the establishment of the cooperation between both of partners and within the research work on the topic.

In Zlín, 20.11.2017
Radek Stoček

Outline

A MODEL TO DESCRIBE THE CRYTALLISATION OF RUBBER UNDER STRAIN AND TEMPERATURE

Alexander Lion* and Michael Johlitz

Institute of Mechanics, Universität der Bundeswehr München,
Werner-Heisenberg-Weg 39, 85579 Neubiberg, Germany

*Corresponding author: alexander.lion@unibw.de

ABSTRACT

For many technical applications of elastomers the understanding and the simulation of the crystallization behaviour are of large interest. The durability behaviour of natural rubber is strongly influenced by strain-induced crystallisation. In order to simulate the properties of natural rubber under thermal or mechanical loads, constitutive models describing the crystallisation are needed. To represent this behaviour, the model for the specific free energy is based on a hybrid formulation: the volumetric part of the free energy is described by an energy function of the Gibbs type whereas the isochoric part is modelled by an energy function of Helmholtz type. Both parts are assumed to be the sums of several terms which are weighted by their mass fractions. The first contributions are the chemical potentials of the amorphous and the crystalline phase as well as an interphase which cannot crystallize. The two remaining contributions are the specific enthalpy and entropy of mixing. The degree of crystallinity is defined by the mass fraction of the crystalline phase and is an internal variable. The mass fraction of the interphase is assumed to be proportional to that of the crystalline phase. For simplification, the expression for the entropy of mixing is formulated using the approach of ideal mixtures. Evaluating the Clausius-Duhem inequality leads to evolution equations for the degree of crystallinity, the deviatoric part of the stress tensor, the specific entropy and the process-induced changes in the specific volume.

The most significant properties of the developed theory are visualized by numerical simulations. Its time-independent equilibrium solution delivers an expression in closed form for the equilibrium degree of crystallinity which depends on the strain and on the temperature. The model also represents the characteristic behaviour of the isobaric specific heat and the specific volume during heating and cooling. It also describes strain-induced crystallisation and its influence on the stress response of elastomers under large deformations.

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HOW TO DETERMINE AGEING OF POLYMERS? BASISCS, EXPERIMENTAL METHODS AND MODELLING APPROACHES

Michael Johlitz*,
Ludmila Sekerakova, Bruno Musil, Alexander Herzig and Alexander Lion

Institute of Mechanics, Universität der Bundeswehr München,
Werner-Heisenberg-Weg 39, 85579 Neubiberg, Germany

*Corresponding author: michael.johlitz@unibw.de

ABSTRACT

Polymers and polymer components are highly important in industrial applications such as bearings, seals, bonds and coatings. Since these components are used in various areas of engineering, it is obvious that they are exposed to different environmental influences such as mechanical stresses, temperature profiles and chemical or biological substances. Therefore, their properties change over time leading to limited operating times. Representative examples are the high-cycle fatigue as a result of the exposure of polymer components to mechanical load collectives, the physical ageing of lacquer coatings or the thermooxidative ageing of elastomeric bearings in ships and automobiles.

In order to estimate the lifetime of the above mentioned polymers in relation to their field of application, there is a great interest to develop new simulation methods and software tools that are able to consider complex long-term processes in the framework of multiphase continuum mechanics. This is the point where the proposed contribution attaches.

At first, the state of the art is presented in relation to the various ageing phenomena and highlighted by scientific data. Both results from the areas of mechanical fatigue, physical and chemical ageing are discussed.

In a next part of the presentation, the experimental equipment which is necessary for ageing and durability studies is introduced. According to that, typical experimental data are shown and analysed. On the one side, these data result from recent literature. On the other side, comprehensive investigations performed at our institute are provided.

From the theoretical point of view, different modelling approaches are introduced and formulated by using the Clausius-Duhem inequality. The evaluation of coupled equations poses a particular challenge, since it involves physical processes that occur on different time scales. In addition, the model should exhibit a physically-based modular structure such that a clear identification of all material parameters is possible.

Meaningful numerical simulations demonstrate that the newly developed models which were implemented into a robust finite element code are able to represent the experimentally observed material behaviour. The contribution is closed by a summary and various outlooks to future trends and objectives.

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THE INTRINSIC STRENGTH OF THERMALY AGED NATURAL RUBBER/BUTADIENE RUBBER BLENDS.

Radek Stoček

Centre of Polymer Systems, University Institute, Tomas Bata University in Zlín, třída Tomáše Bati 5678, 760 01 Zlín, Czech Republic

Corresponding author: stocek@utb.cz

ABSTRACT

Tires require rubber compounds capable of enduring more than 10^8 deformation cycles without crack growth. One strategy for evaluating candidate compounds is to measure the intrinsic strength. The intrinsic strength is the residual strength remaining in the material after the strength-enhancing effects of energy dissipation in crack tip fields are removed. If loads stay always below the intrinsic strength (taking proper account of the possibility that the intrinsic strength may degrade with aging), then cracks cannot grow. Using the cutting protocol proposed originally by Lake and Yeoh (1978), as implemented on a commercial Intrinsic Strength Analyzer, the intrinsic strength is determined for a series of carbon black (CB) reinforced blends of natural rubber (NR) and butadiene rubber (BR) typical of tire applications. The intrinsic strength benefits of the blends over the neat NR and BR compounds are only observed after aging at temperatures in the range from 50°C to 70°C, thus providing fresh insights into the widespread durability success of CB-filled NR/BR blends in tire sidewall compounds and commercial truck tire treads.

REFERENCES

Lake, G. J. and Yeoh, O. H., “Measurement of Rubber Cutting Resistance in the Absence of Friction,” International Journal of Fracture, Vol. 14, 1978, pp. 509-526.

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THE STUDY OF FATIGUE BEHAVIOR OF THERMALLY AGED RUBBER BASED ON NATURAL RUBBER AND BUTADIENE RUBBER

Ondřej Kratina [1 *], Radek Stoček [1],
Bruno Musil [2], Michael Johlitz [2], Alexander Lion [2]

[1]Centre of Polymer Systems, University Institute, Tomas Bata University in Zlín, třída Tomáše Bati 5678, 76001 Zlín, Czech Republic

[2]Institute of Mechanics, Universität der Bundeswehr München, Werner-Heisenberg-Weg 39, 85579 Neubiberg, Germany

*Corresponding author: okratina@utb.cz

ABSTRACT

The aim of this work is investigation of the influence of thermal aging on fatigue behavior of carbon black filled rubber compounds which have been based on Natural rubber (NR), Butadiene rubber (BR) and their blend with ratio 50/50. The thermal aging was performed using hot air oven at varied temperatures 30, 70 and 110 °C for 720 hours. At first, the influence of thermal aging on mechanical behavior under quasi-static tension has been performed by tensile test machine. The influence on dynamic behavior has been determined by dynamic mechanical analysis (DMA). The fatigue behavior under sinusoidal waveform loading conditions has quantitatively been analyzed by using of dynamic testing equipment Tear and Fatigue Analyzer. This work is focused to investigate the influence of thermal aging on the fatigue behavior of rubber based on varied rubber types to understand the relationship between the thermal degradative processes occurred in rubber matrix under thermal aging and fatigue life. From the experimental work it was concluded based on all used testing methods, that the presence of BR rubber enhances the resistance against thermal aging and thus could be used as an efficient component reducing the aging degradation in rubber blend systems.

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FRICTIONAL BEHAVIOUR OF AGED NATURAL RUBBER

Evghenii Harea* and Radek Stoček

Centre of Polymer Systems, University Institute, Tomas Bata University in Zlín,
třída Tomáše Bati 5678, 760 01 Zlín, Czech Republic

*Corresponding author: harea@cps.utb.cz

ABSTRACT

The growing interest for aging of rubber vulcanizates starts from early 1945, when Symposium on the physical and chemical breakdown of rubbers was organized in Birmingham, England. Historically, attention has been given to changes in tensile strength resulting from conditioning of rubber at elevated temperatures for specified periods of time.

During the time, rubber typically becomes harder and loses its flexibility and fatigue. The aging process is a chemical change of material due to thermodynamic reaction, which strongly affects all mechanical properties and in the end determine life time of product.

In the present work, sulphur cured natural rubber (NR) sheet of 2 mm thickness was thermally aged at 90°C for 30 days. The main goal was to study the frictional behavior of aged NR at different tribological testing parameters such as friction speed and load.

Friction is the surface interaction in moving contact between frictional partners. The tribological mechanism in rubber are quite different than mechanisms involved in hard materials like metals or ceramics. Is well known, that during hard ball sliding on soft rubber surface, regular folds are created in direction of motion as a result of complicated compression-tension distribution around the contact area.

Besides friction coefficient, wear is also an important behaviour of any rubber composites. Friction wear usually is a combination of several parameters which include the contact pressure, temperature, and sliding velocity. Contrasting to the sliding wear of hard materials, elastomers involve complex wear mechanisms, which are affected by “waves of detachment” apparition and create characteristic abraded surface.

It was found that ageing generally decrease friction coefficient of investigated samples and significantly increase wear. Coefficient of Friction (COF) displayed essential decreasing for all studied samples when applied load rise. If sliding speed increase, then COF became bigger. In contrast, wear increase for higher load and higher speed.

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RETENTION OF AFTER AGEING PROPERTIES OF GROOVED RUBBER PADS BASED ON NATURAL RUBBER

Sanjoy Datta* and Radek Stoček

Centre of Polymer Systems, University Institute, Tomas Bata University in Zlín, třída Tomáše Bati 5678, 760 01 Zlín, Czech Republic

*Corresponding author: datta@uni.utb.cz

ABSTRACT

Cured rubber products undergo oxidative ageing and it is customary to suppress it as much as possible to increase the service life of any such product. Though natural rubber (NR) products exhibit very good initial mechanical properties, in some respects even superior to those of styrene butadiene rubbers (SBR), yet, unfortunately, on a comparative basis, they are also more susceptible to ageing. In the present work, two different recipies were mixed and cured meant to arrest the accelerated ageing of a specific product called the grooved rubber pads (GRP), without significantly sacrificing the mechanical and electrical properties. Rubber Pad is used to reduce the vibrations and noise caused by the trains. One formulation was based on a 70:30 weight ratio of NR and SBR while the other was based on only NR as the rubber of choice. Of course, a better choice of the pristine polymer would have been chloroprene rubber (CR) but at the cost of much higher priced products. Properties such as hardness, tensile strength, relaxed modulus at 100 % elongation, elongation at break percent, static load deflection, electrical resistance in dry condition as well as after water immersion for a specified period of time, tension set, compression set and after ageing retention of the mechanical properties were determined. It was found that in both the cases, the formulations were good enough to satisfy the after ageing retention of the required properties. However, since the initial properties were somewhat superior in case of the product formulated with NR, so it was taken as the ultimate formulation.

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INFLUENCE OF ANTIOXIDANT TYPE ON THE AGING OF RUBBER VULCANIZATES

Katrin Reincke[1*], Katja Oßwald[1], Selin Sökmen[1,] Beate Langer[1,2] and Wolfgang Grellmann[1, 3]

[1]*Polymer Service GmbH Merseburg, Eberhard-Leibnitz-Str. 2, D-06217 Merseburg, Germany*

[2]*Hochschule Merseburg, Eberhard-Leibnitz-Str. 2, D-06217 Merseburg, Germany*

[3]*Martin-Luther-Universität Halle-Wittenberg, D-06099 Halle, Germany*

*Corresponding author: katrin.reincke@psm-merseburg.de

ABSTRACT

Former investigations (Reincke et al, 2015) of a carbon-black filled styrene–butadiene and a natural rubber vulcanizate (SBR and NR) showed clear differences in the degradation behaviour of the used antioxidant during an artificial weathering. Beside this, a change in material properties was observed, which could however not be attributed to a decomposition of the polymer network or chain scission. Now, in a further study, the behaviour during thermo-oxidative aging and artificial weathering was investigated also for unfilled and carbon-black filled SBR and NR vulcanizates. Due to the results of the former study, three different antioxidants IPPD, 6PPD and TMQ were used. Additionally, the carbon-black content was varied. The duration of the thermo-oxidative aging was 250 h, 500 h, 1500 h and 2000 h and three different temperatures (23 °C, 40 °C and 80 °C) were realized. The artificial weathering war realized also up to 2000 h. To characterize the material properties in dependence on the aging time and temperature as well as type of antioxidant, different methods were applied. The tensile, tear test and hardness measurement gave the general mechanical properties and by using dynamic mechanical analysis, the influence on the Payne effect was studied. Additionally, a light microscope was used to characterize the surfaces of the samples before and after artificial aging.

REFERENCES

K. Reincke, M. Schoßig, S, Poser, B. Langer, S. Döhler, U. Heuert, W. Frank, W. Grellmann, Experimental Characterization of the Ageing Resistance of Elastomers, European Conference on Constitutive Models for Rubbers, ECCMR, 2015, Prague, September 1st – 4th IX, 2015, Proceedings p. 33–37.

THERMO-MECHANICAL ANALYSIS OF STEADY STATE ROLLING TIRES WITH RESPECT TO THERMAL DAMAGE

Michael Kaliske* and Ronny Behnke

Institut für Statik und Dynamik der Tragwerke, Technische Universität Dresden, 01062 Dresden, Germany

*Corresponding author: michael.kaliske@tu-dresden.de

ABSTRACT

The thermo-mechanical analysis of tires is a first step towards a more realistic numerical model for these complex structures. To study further aspects besides stresses and temperatures in the tire, other submodels have to be incorporated into the analysis process, e.g. thermal damage.

In this contribution, thermal material degradation in steady state rolling tires is numerically studied using the example of an off-the-road (OTR) tire. OTR tires, e.g. for earth-movers, are complex and large structures made of different rubber compounds and reinforcement cords. The load-induced deformations of the tire in service lead together with the dissipative nature of the rubber compounds to a heat build-up in the tire's cross-section and, in consequence, to thermal material degradation in highly heated regions. A phenomenological (1 – d) thermal damage approach is implemented into a modular simulation environment, which allows the thermo-mechanically coupled analysis of axisymmetric tires in steady state motion. The sequentially coupled thermo-mechanical simulation approach is based on the finite element method (FEM) and uses an Arbitrary Lagrangian Eulerian (ALE) framework to represent the rotation of the tire. Effects stemming from rotation-induced inertia forces and temperature-dependent viscoelasticity of the rubber compounds at finite deformations are included in the mechanical response of the rolling tire. Energy losses as heat source terms, computed on a physical basis from the dissipative material properties (non-equilibrium stresses), are used to predict the heat build-up during service for different operation modes of the tire. The thermal damage approach qualitatively captures the irreversible changes of the rubber compounds' mechanical properties, which, in turn, result in an alteration of the entire structural response of the tire.

Different thermal damage evolution equations have been implemented into the afore-mentioned sequentially coupled thermo-mechanical analysis scheme to numerically represent thermal damage within tire simulations.

Although the phenomenological (1 – d) thermal damage approach allows capturing irreversible damage phenomena due to overheating in the tire structure, irreversible alterations will normally occur in combination with other damage types, e.g. discrete cracks, delamination of the rubber matrix from reinforcement cords, failure of cords. In addition, an experimental investigation with respect to thermal durability of each rubber compound is required to carry out quantitative predictions on the material scale as well as on the structural scale.

CHEMICAL ASPECTS OF THERMOMECHANICAL DEGRADATION OF RUBBERS

Vratislav Ducháček

Department of Polymers, University of Chemistry and Technology, Technická 1905/5, 166 28 Prague 6, Czech republic

Corresponding author: Vratislav.Duchacek@vscht.cz

ABSTRACT

From the broad point of view, aging of polymers includes degradation, i.e. changes in their chemical and physical properties due to external chemical and/or physical stresses leading to materials with properties differing from those of the original material. Usually, degradation means worsened properties.

According to the chemical and physical structure, polymeric materials including vulcanized rubbers are harmfully attacked by effects of environment, i.e. oxygen, ozone, humidity and atmospheric pollutants; by physical stresses as heat and mechanical forces; by radiation.

According to processes taking place, they are classified as melt degradation, heat aging, and weathering. According to mechanisms, the processes are thermal or thermomechanical oxidations.

As far as in 1897 Engler and Bach have developed a theory of thermo-oxidation of materials leading to peroxides. Chemiluminiscence has been used to show the participation of $R^{\cdot}$ and $RO_2^{\cdot}$ in oxidation reactions of polymers.

The initiation step of thermo-oxidation accounts for macroradicals $R^{\cdot}$ and $HO_2^{\cdot}$ formed from a rubber RH by its reaction with oxygen. Propagation is based on a reaction of $R^{\cdot}$ with oxygen leading to $RO_2^{\cdot}$ radicals and their following reaction with rubber hydrocarbon leading to ROOH hydroperoxides. This is the rate determining step. The abstraction of a hydrogen atom from a rubber chain is done by intramolecular and/or intermolecular reactions. Termination is based on mutual reactions of radicals leading to nonreactive products.

The initiation step of thermomechanical degradation accounts for macroradicals $R^{\cdot}$ formed from a rubber RH by shear and/or thermal treatment. Macroradicals $R^{\cdot}$ are formed via statistical breaking C-C bonds or C-H bonds. During propagation they react very effectively with even trace amounts of oxygen present in the material. Alkylperoxy radicals arise in the first step and are transformed by a chain mechanism into alkylhydrooperoxides and products of their thermolysis, alkoxyradicals, and carbonyl compounds. In systems with low steric hindrance in the chains, such as ethylene-propylene rubbers, addition of macroalkyls to unsaturation is possible and accounts for another carbon-centered free radical. In termination steps macroalkyls are transformed by disproportionation or recombination accounting for branching and crosslinking formation.

All these reactions are possible in thermomechanical degradation of polymer blends including rubber mixtures. Of course, the processes are more complicated and include reactions in the bulk of individual

components (rubbers) and potentially cross-reactions between macroradicals arising from different polymers (rubbers), accounting for in situ formation of grafted copolymers with the potential function of compatibilizers. It is expected that the graft copolymers are formed on interfaces between phases consisting of individual polymers (rubbers).

Primary antioxidants that interrupt the oxidation chain reaction react with active radicals $ROO^{\cdot}$ to produce less active ones. This mechanism holds mainly for phenol derivatives where the inactive radical is stabilized by resonance but not for aromatic amines. As it is generally known, aromatic amine-type antioxidants are used for dark-coloured materials intended only for technical applications due their and/or their decomposition products staining effects. The most commonly used are secondary amines and p-phenylene diamine derivatives.

INFLUENCE OF THERMAL DEGRADATION OF BUTYL RUBBER COMPOUND

Zdeno Plevák

Continental Matador Rubber,s.r.o., Terezie Vansovej 1054, 020 01 Púchov, Slovak Republic

Corresponding author: zdeno.plevak@conti.sk

ABSTRACT

The effect of different selected types of carbon black on cure characteristic, rheological and mechanical properties of blend of isobutylene-isoprene rubber and chloroprene rubber with focus on stability of the properties after thermal aging were investigated. The carbon black coding for each investigated carbon black type was designated with the aim to keep stable reinforcement effect of the rubber compound. The range of carbon black from Super Abrasion Furnace black (SAF) up to Semi Reinforcing Furnace (SRF) carbon black were selected. The individual rubber compounds were mixed by Banbury laboratory mixer. Samples were vulcanized using electric press. There was observed that rubber compound with Super Abrasion Furnace black (SAF) carbon black has lower change of mechanical properties when were compared mechanical properties before and after thermal aging in comparison with Semi Reinforcing Furnace (SRF) carbon black which means that rubber compound with usage of Super Abrasion Furnace black (SAF) carbon black was much more stable after thermal aging.

THE DYNAMIC AGEING OF VULCANIZATES - - DMA METHOD VS. CRACK GROWTH RATE

Jana Voldánová [1]*, Radek Stoček [2], Jiří Maláč [3]

[1]*Mitas a.s., Ulice Šedesátá 5638, 762 02 Zlín, Czech Republic*

[2]*Centre of Polymer Systems, University Institute, Tomas Bata University in Zlín, třída Tomáše Bati 5678, 76001 Zlín, Czech Republic*

[3]*Department of polymer engineering, Faculty of Technology, Tomas Bata University in Zlín, nám. T. G. Masaryka 275, 762 72 Zlín, Czech Republic*

*Corresponding author: jana.voldanova@trelleborg.com

ABSTRACT

Thus the aim of this study is to determine the influence of thermal aging processes in air environment and in the wide temperature range, which closely resembles the tire application environment in the field. In the present study, Fatigue Crack Growth (FCG) behavior of varied industrial blends directly suitable for treads applied in agricultural tires, have been investigated. A new parameter based on loss compliance factor has been identified for describing the embrittlement or softening/hardening of aged rubber matrix by using of dynamic mechanical analysis (DMA). These evaluated data have been compared with the fatigue crack growth parameters observed by the using of a dynamic testing machine, Tear and Fatigue Analyzer (TFA) simulating the loading conditions of tire. The correlation between loss compliance parameter and fatigue crack growth data has been evaluated and explained. The loss compliance factor has been determined to be a suitable parameter predicting the behaviour of rubber materials affected by higher temperature.

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INFLUENCE OF THERMAL AGEING ON MECHANICAL PROPERTIES OF STYRENE-BUTADIENE RUBBER

Iva Petríková*, Bohdana Marvalová and Phan Thanh Nhan

Technical University of Liberec Studentská 2, Liberec, Czech Republic

*Corresponding author: iva.petrikova@tul.cz

ABSTRACT

The mechanical properties, the temperature dependence of dynamic behaviour of SBR and post-thermal ageing properties of styrene-butadiene rubber (SBR) were investigated. The rubber specimens were heated at a temperature of 100 °C in a ventilated air oven with natural convection for 1, 3, 7, 14 and 21 days, respectively. The specimens were then tested in the tensile strength, elongation at break and their dynamic mechanical properties were determined by means of DMA at different frequencies and amplitudes. The dependence of the hardness ShA on the ageing was also investigated.

EXPERIMENTAL DETERMINATION OF THE MECHANICAL PROPERTIES OF NATURALLY AGED RUBBER

Iva Petríková*, Bohdana Marvalová

[1]Technical University of Liberec Studentská 2, Liberec, Czech Republic

*Corresponding author: iva.petrikova@tul.cz

ABSTRACT

The aging effects on the dynamical and tribological properties of naturally aged segments of Polyisoprene/Polybutadiene Rubber Blend (IR/BR) with a different service history were investigated experimentally. Specimens sliced from segments were subjected to a series of static and relaxation tests, to dynamic mechanical analysis, and to hardness and friction measurements. Rubber becomes harder in the course of aging, loses its damping capability, and the properties determining its friction behaviour change and friction coefficient are reduced in comparison with the virgin state.

INTRINSIC STRENGTH OF CARBON BLACK FILLED RUBBER

R. Stoček[1*], W.V. Mars[2],
O. Kratina[1], A. Machů[1], M. Drobilík[1], O. Kotula[1], A. Cmarová[1]

*[1] Centre of Polymer Systems, University Institute, Tomas Bata University in Zlín,
třída Tomáše Bati 5678, 760 01 Zlín, Czech Republic*

[2]Endurica LLC, Findlay, Ohio, USA

*Corresponding author: radek.stocek@prl-z.com

ABSTRACT

The intrinsic strength was evaluated for EPDM, with varied carbon black type N330, N550 and in the volume 50, 70 and 90 phr. The measurement was based on quasi-static tension loading on an edge-cracked pure shear specimen, combined with frictionless cutting via a sharp blade. The cutting force and pre-stress parameters were varied automatically using the Intrinsic Strength Analyzer (ISA©) instrument manufactured by Coesfeld GmbH. It was observed that the intrinsic cutting energy decreases with increase of carbon black and the dominant effect of the carbon black particle diameter has been determined.

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RHEOLOGICAL PROPERTIES OF RUBBER BLENDS USED TO RUBBER COATING OF METAL CORDS

Martina Matvejová [1]*, Jozef Feranc [1], Pavol Alexy [1], Ivan Hudec [1], Jozef Preťo [2], Ján Hronkovič [2]

[1]*Institute of Natural and Synthetic Polymers, Slovak University of Technology, Radlinského 9, 812 37 Bratislava, Slovak Republic*

[2] *Vipo, a.s , Generála Slobodu 1069/4, 968 01 Partizánske, Slovak Republic*

*Corresponding author: martina.matvejova@gmail.com

ABSTRACT

In rubber industry focused to rubber coating, extrusion technology is used. As with other technologies, also in the extrusion, there are problems which are mainly related with rheological properties of processed material. This is the reason to know complex behaviour of processed rubber material. Because of fact that extrusion runs at shear rates of thousands per second, it is suitable to use capillary rheometer for measuring rheological properties. However, rubber blends have a certain specific features. Besides higher viscosity it is also the higher part of elastic deformation, which shows mainly for the measurement in the range of high shear rates.

The aim of work is focused to measure of rheological properties of commercial rubber blend based on NR which is used for rubber coating of metal cords.

As measurement device was used capillary rheometer Göttfert RG 75 with diameter of chamber 15 mm. Measurements were performed using capillary with different ratio of length to diameter at temperature 100 °C. Because of the high viscosity of material, the isobaric mode of measurement was used. At a selected pressure in this mode, the shear rate needed to achieve the desired pressure is compared.

By this work it is confirmed that using of a capillary rheometer is appropriate because we achieved the shear rates at which the extrusion process is running in contrast to oscillatory rheometer. Also flow through capillary better simulate movement of rubber material during extrusion. These measurement allow correctly describe the behaviour of the system and determine the maximum shear rate at a given geometry (length, diameter) of capillaries. Chamfer of the capillary inlet will have also significant influence for measuring rheological properties.

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ELASTOMERIC COMPOSITES FILLED WITH MAGNETIC FILLER

Andrea Kvasničáková[1]*, Ján Kruželák[1], Ivan Hudec[1] and Rastislav Dosoudil[2]

[1] Department of Plastics, Rubber and Fibres, Faculty of Chemical and Food Technology, Slovak University of Technology in Bratislava, Radlinského 9, 812 37 Bratislava, Slovakia

[2] Department of Electromagnetic Theory, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava, Ilkovičová 3, 812 19 Bratislava, Slovakia

*Corresponding author: andrea.kvasnicakova@stuba.sk

ABSTRACT

Composite materials filled with ferrite particles based on polymer matrix materials are of current research interest due to possible applications. The unique feature ensuring their wide prospects in various research fields, is the strong dependence of the mechanical properties on the applied magnetic field. Magnetic properties of the polymer magnetic composite materials depend on the shape and type of filler and on chosen manufacturing technology.

Elastomer magnetic composites were prepared by incorporation of barium ferrite into rubber matrix based on acrylonitrile butadiene rubber and natural rubber. Besides rubber and filler, the rubber composites contained only ingredients necessary for the curing process. The peroxide and sulfur curing systems were applied for cross-linking of rubber compounds. The aim was to investigate the influence of barium ferrite and curing sytem composition on the vulcanization process and cross-link density of prepared materials.

The incorporation of barium ferrite in the rubber led to elastomeric materials with magnetic properties. The mutual interactions between the filler and rubber matrices were investigated by determination of cross-link density. Crosslink density of the vulcanizates was determined by equilibrium swelling in acetone and xylene. In addition, physical-mechanical and magnetic characteristics were investigated in relation to the cross-link density and structure of the formed cross-links. The results demonstrated that the composition of curing system and the type of cross-link structure within the rubber matrix influence physical-mechanical properties of vulcanizates. Moreover, the type of curing system has no significant influence on the tested magnetic characteristics.

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THE INFLUENCE OF THE PROCESSING CONDITIONS ON THE DIELECTRIC PREHEATING OF NATURAL RUBBER, FIRE RISKS

David Pospěch[1,2], Michal Sedlačík[1], and Zdeněk Dvořák[1*]

[1]Department of Production Engineering, Faculty of Technology, Tomas Bata University in Zlín, Vavrečkova 275, 760 01 Zlín, Czech Republic

[2]Continental Barum, Objízdná 1628, 765 02 Otrokovice, Czech Republic

*Corresponding author: zdvorak@utb.cz

ABSTRACT

The aim of this work is to determine the limit process conditions of dielectric heating (DE) of the basic rubber material - natural rubber, entering the process of production of rubber mixtures, with regard to the safety of operation. Materials suitable for DE heating are generally called dielectrics. Dielectrics are insulators that have the ability to be polarized. Although the dielectric contains no free electrical charges and appears to be neutral, it is composed of a large number of elementary particles that contain electrical charge (eg atoms, functional groups, ions, etc.). The external electric field, which affects the elementary particles in dielectrics, affects the distribution of electrical charge in the dielectric. Changed charge distribution then in turn affects the external electric field. By introducing the dielectric into an electric field, a phenomenon called dielectric polarization occurs. In the rubber industry, a great deal of materials is used for the production of rubber mixtures. However, raw materials are not always delivered in an ideal state (ready for immediate processing). Their further preparation is logically derived from used processing technologies as well as used machinery. Some of them should be preheated to the processing temperature. From the point of view of applying microwave technology, following materials are relevant: natural and synthetic rubber, softeners, and made rubber compounds. Other components are included in the mix according to DSK (parts per 100 rubber parts), in a relatively small amount. There is no need to preheat these. The preheating of the rubber before processing is a very important part of the technological process of the rubber compound production. Especially from an economic point of view, but also from a production point of view. When preheated rubber is being processed, production time is significantly shortened, energy consumption is reduced and the service life of the machine is also increased. In order to ensure a balance between the production efficiency and the quality of the blending technology of the rubber mixtures, it is not necessary to preheat input material above about 45 ° C. At this temperature, the rubber will be ready for thermal kneading, but at the same time the mechanical part of the blending process of the rubber mixtures will not be suppressed, which is of no less importance. DE preheating of natural rubber has been known for many years, yet there are still undesirable effects leading to fires. Operators are not always able to ensure the utmost security of this technology. The consequences of these crisis situations are usually fatal. The cost of production restart is often very high. The primary objective of this work is to investigate the course of these non-standard and undesirable situations, where the fires of DE devices undoubtedly belong. One of the undesirable phenomena is the so-called hot spot, or hot zone, arising due to inhomogeneity of heated material or electromagnetic field. Temperature of these hot spots can exceed the ambient temperature in the exposed material by several orders of magnitude, which in turn may and often causes local, degradative changes and a possible fire.

DIELECTRIC PREHEATING OF RUBBER MIXTURES

David Pospěch[1,2], Michal Sedlačík[1], and Zdeněk Dvořák[1*]

[1]*Department of Production Engineering, Faculty of Technology, Tomas Bata University in Zlín, Vavrečkova 275, 760 01 Zlín, Czech Republic*

[2]*Continental Barum, Objízdná 1628, 765 02 Otrokovice, Czech Republic*

*Corresponding author: zdvorak@utb.cz

ABSTRACT

The processing of rubber compounds in the rubber industry is highly energy demanding. To transform the rubber compound into a plastic state, in which further processing is possible, a huge amount of energy is required. Firms involved in the processing of rubber compositions use mechanical energy in most cases, in particular from roll rubber mills or extruders. The required heat energy generated by the considerable mechanical friction of the material on the walls of the processing machines is at a cost of a high power consumption. Efficiency itself thus decreases considerably in such machines and a careful consideration of economic aspects is in place. These machines are not very suitable for small-scale production with frequent or even cyclic shutdowns. Restarting and setting optimal operating conditions is cost-effective from an economical point of view and the price of the final product increases considerably. This problem is well understood by processors, and therefore efforts are increasingly being made to introduce new technologies to ensure more efficient use of energy resources. One solution can utilize the dielectric heating of the prepared materials. At present, this technology is used in many processing branches. The efficiency of dielectric devices is indisputably higher than with conventional methods of heating the materials being processed and, in principle, more advantageous. The heated material absorbs energy in the whole volume which substantially reduces the necessary technological time of the whole operation and thus also contributes to the positive reduction of the economic balance of the process. By introducing this technology into rubber plants, such as tire production, the door could be opened up to new possibilities with considerable cost savings. However, a thorough knowledge of the properties of rubber materials and optimal operating conditions are required. The aim of this work was to select suitable representatives of rubber mixtures, which are commonly processed in rubber plants, examine their dielectric properties and their overall potential for preheating, post-processing, using dielectric technology. Two completely different categories of mixtures were deliberately included in the final selection of the rubber mixtures, both in terms of their material composition and processing. All of the selected rubber blends have been tested on modern laboratory devices where their ability to interact with microwave radiation has been investigated. The overall benefit of this work was the energy comparison of the conventional and proposed way of preheating of rubber mixtures before they enter into subsequent technological processing in rubber plants.

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