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DEVELOPMENT OF AN IMITATION MODEL OF THE VULCANIZATION PROCESS IN THE PRODUCTION OF ELASTOMERIC COMPOSITES.

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Abstract: *In the article, a systematic approach to the mathematical modeling of the production process of complex multi-stage elastomeric composites was considered, which allows to take into account the stoichiometric relationship of the chemical reaction in the process. Based on the chemical reaction occurring in the mixer, a kinetic model of the elastomer composites production process is proposed, which is the basis for obtaining the main functional relationship of the mathematical model for the mixer, the main quality indicator of the process. The proposed systematic approach in the form of a mathematical model based on the stoichiometric relationship and the reversibility coefficient of a chemical reaction makes it possible to create a quality control system for a chemical process and to justify the rationality of the structure of the model built for the purpose of rapid control of the reversible chemical process object.*
Key words: *elastomer composites, mathematical model, stoichiometric matrix, chemical reaction, principal components, simulation model, concentration, Matlab, optimization.*

Annotatsiya: *Maqolada murakkab ko'p bosqichli elostomer kompozitlar ishlab chiqarish jarayonini matematik modellashtirishda tizimli yondashuv masalasi ko'rilgan bo'lib, u jarayonda kimyoviy reaksiyaning stexometrik munosabatni hisobga olish imkonini beradi. Aralashtirgichda sodir bo'ladigan kimyoviy reaksiya asosida elostomer kompozitlar ishlab chiqarish jarayonini kinetik modeli taklif etilgan bo'lib, u jarayoning asosiy sifat ko'rsatkichi – aralashtirgich uchun matematik modelning asosiy funksional munosabatini olishga asos bo'ladi. Stexiometrik munosabat va kimyoviy reaksiyaning qaytarilish koeffitsiyentiga asoslangan matematik model ko'rinishida taklif etilgan tizimli yondashuv kimyoviy jarayon uchun sifat ko'rsatkichlari bo'yicha boshqarish tizimini yaratish va qaytariluvchi kimyoviy jarayon obyektini tezkor boshqarish maqsadida tuzilgan modelning strukturasini oqilonaligini asoslash imkonini beradi.*
Tayanch so'zlar: *elastomer kompozitlar, matematik model, stexiometrik matritsa, kimyoviy reaksiya, asosiy komponentlar, imitatsion model, konsentratsiya, Matlab, optimallashtirish.*

Аннотация. *В статье рассмотрен системный подход к математическому моделированию процесса производства сложных многоступенчатых Элостомерных композитов, позволяющий учесть стехиометрическую зависимость химической реакции в процессе. На основе протекающей в смесителе химической реакции была предложена кинетическая модель процесса производства Элостомерных композитов, которая послужила основой для получения основного качественного показателя процесса-основного функционального отношения математической модели к смесителю. Предложенный подход в виде математической модели, основанной на стехиометрическом соотношении и коэффициенте обратимости химической реакции, позволяет создать систему управления химическим процессом по качественным показателям и обосновать рациональность структуры модели, построенной с целью оперативного управления объектом обратимого химического процесса.*
Ключевые слова: *эластомерные композиты, математическая модель, стехиометрическая матрица, химическая реакция, основные компоненты, имитационная модель, концентрация, MATLAB, оптимизация.*

Introduction

Currently, in the field of control system engineering in the world practice, the process of creating control systems with high efficiency, based on the achievements of intellectual technologies of technological processes, occupies a leading place. In a rapidly developing modern Information Society, the control of real dynamic systems based on the analysis and processing of very large data flows is one of the actual problems. The control of technological processes in production enterprises on the basis of an intellectual system has opened a new direction in the field. The use of programs in the task of human intelligence in the automation and control systems of technological processes has given rise to the formation of intellectual control systems.

In order to solve the problems of optimization and control of vulcanization modes, it is necessary to find out the complex structural complexes of elastomers, as well as information about their structure and basis of processes. Currently, in the rubber industry, a method is used to solve many issues, based on providing the process as a sequence of individual stages. The stages include the below: induction period, structuring, and reproducibility.

To calculate the process in production conditions, it is required to carry out a large number of full-scale experiments and to develop calculations and algorithms that provide adequate models of the process. To do this, at the first stage, it is necessary to analyze the probability mechanisms of reactions of the structural process and their interaction with each other.

To solve these issues, only a series of full-scale experiments on the plan can be carried out after calculating the reserve options of models that allow you to establish the mechanism of reactions involved in the structuring process.

Research Methods and the Received Results

In the preparation of elastomer composites, traditional methods do not provide the ability to analyze the process, take into account and distinguish the processes of structural and interruption. This does not allow them to be used for industrial rubber analysis. Thus, the existing methods of analysis and calculation of kinetic properties are not universal and cannot be used in rubber production under a wide range of technological conditions. In this regard, the development of methods and algorithmic supply for the analysis of interconnected processes is a necessary condition for solving problems of optimization and control of vulcanization modes.

When constructing a mathematical description of a process, it is necessary to determine the range of changes of the set of components involved in reactions, the main stages of the process and substantiate the kinetic law of the interaction of components.

Experiments so far have shown the formation of a real vulcanization agent at the stage of preparation of the rubber mixture. This makes it possible to use the law of Mass Effect to describe the main stages of the process.

The formation of a vulcanization lattice under the action of sulfur in volcanic systems, the formation of a vulcanization lattice under the action of sulfur and accelerators on the basis of the kinetic scheme of the process (1)-(4) is as follows.

$$1)\ A \xrightarrow{k_1} B \quad (1)$$

$$2)\ B \xrightarrow{k_2} \mathrm{D} \quad (2)$$

$$3)\ \mathrm{D} \xrightarrow{k_3} \alpha \cdot V_{\mathrm{tt}} \quad (3)$$

$$4)\ A + \mathrm{D} \xrightarrow{k_4} \beta \cdot B \quad (4)$$

Where 1) the addition of A to the elastomeric molecule and the formation of B 2) the decomposition of B 3) the interaction of D with the macroradical results in the rubber molecule's Vul tt vulcanization lattice nodes. 4) crossover. One of the main features of the reaction is that at the initial stage of vulcanization, the phenomenon of thermoflucous scattering of macromolecules occurs-the additional reaction decomposition can depend on semi-sulfidity, the reduction of internchimolecules to the cycle, and other conditions. Thus this scheme cannot fully represent the mechanism of the transition process of a given process.

When expressing the chemical transformation scheme of this process, the illumination of the reaction mechanism should be increased to a higher level. For this reason, in a certain kinetic scheme, additional reactions must be put, which produce micro radical and vulcanizing agent reactions by changing the structure of sulfur molecules.

The correct solution to the problem of solving the correct and inverse Masons of isothermal vulcanization Kinetics is the determination of the time-varying function of the junctions of the concentration generated in this vulcanization. By solving the correct problems of kinetics, let's figure out the solution to the problem in the Koshi equation (5) given in the equation. The kinetic shift line of the process can be determined by M (t) shift moment values. Differential equalities exist-the calculation is done by a numerical method. Solving the inverse problems of the process is the identification of model parameters, and constants: reaction rate, stoichiometric coefficients, and variables are derived. When the solution of inverse problems of Kinetics is applied, bounded and unbonded methods of optimization are used. Solutions to the correct issues of kinetics and the inverse of kinetics are implemented using problematic software products developed in an integrated environment in the MATLAB application.

$$
\begin{cases}
\frac{dC_A}{dt} = -k_1 \cdot C_A - k_4 \cdot C_A \cdot C_D \\
\frac{dC_B}{dt} = k_1 \cdot C_A - k_2 \cdot C_B + k_9 \cdot C_M + \beta \cdot k_4 \cdot C_A \cdot C_D \\
\frac{dC_D}{dt} = k_2 \cdot C_B - k_7 \cdot C_D - k_5 \cdot C_D - k_3 C_D + k_6 C_{V_{tbb}} - k_4 \cdot C_A \cdot C_D \\
\frac{dC_{V_{tb}}}{dt} = \alpha \cdot k_3 \cdot C_D \\
\frac{dC_{V_{tbb}}}{dt} = \gamma \cdot k_5 \cdot C_D - k_6 \cdot C_{V_{tbb}} \\
\frac{dC_C}{dt} = \delta \cdot k_7 \cdot C_D \\
\frac{dC_M}{dt} = k_8 \cdot C_R - C_M, \\
\frac{dC_R}{dt} = -k_8 \cdot C_R
\end{cases}
\qquad (5)
$$

Here is a C – concentration of vulcanization agent; CB - concentration of mutual relation; CD - concentration of active mutual connection; CW –concentration of stable vulcanization nodes; CW- concentration of unstable vulcanization nodes; Cc – intramolecular-bounded sulfur concentration; CM – macro radial rubber concentration; CR - rubber concentration; α, β, γ, δ – stoichiometric coefficients; k1, ... , k9 – constant of the reaction kinetics.

The Imitation model of the process in the Matlab commercial software will have the appearance below.

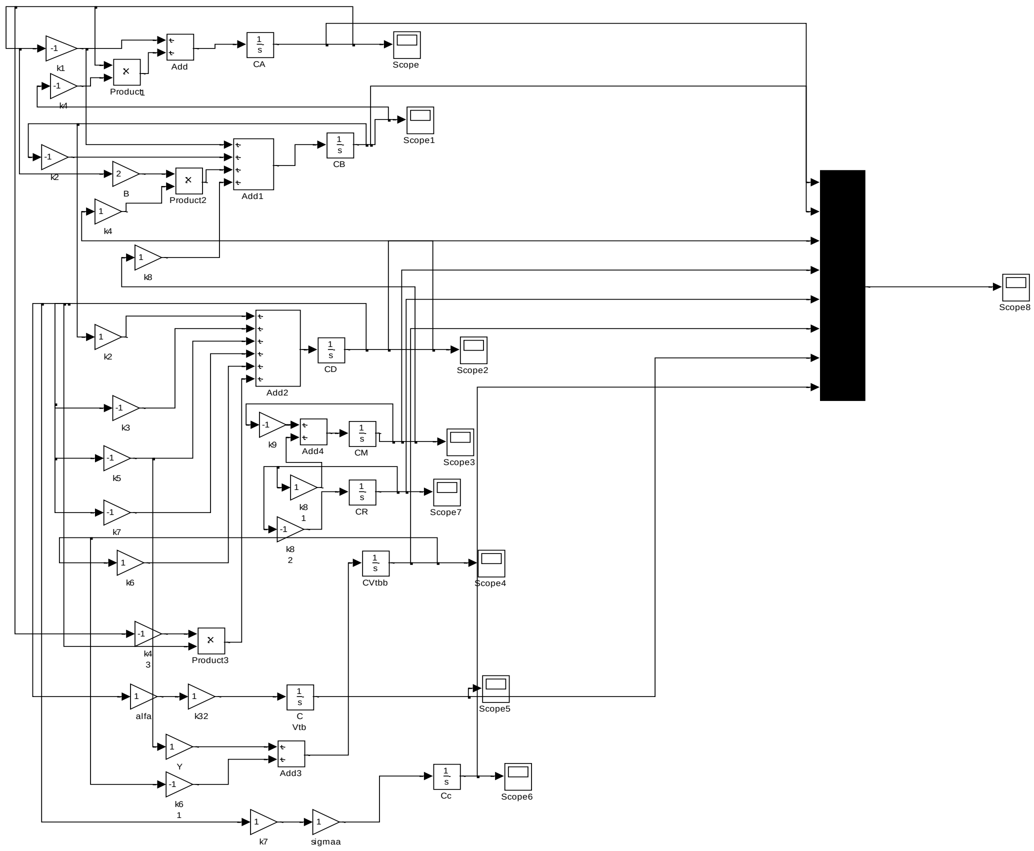

Figure 1. ***Imitation model of the vulcanization process.***

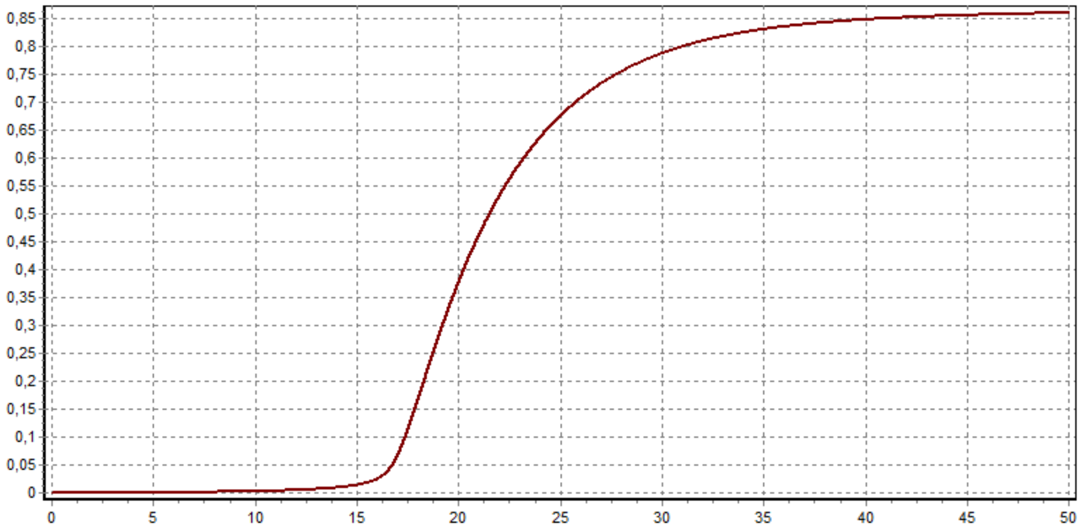

Figure 2. ***Change in concentration of vulcanization over time graphs.***

Conclusion

In the production of elastomeric composites, a mathematical model has been created that provides stabilization of the temperature and concentration in the mixer in the process.

The use of the mathematical model under consideration as part of the mixing process control system in the production of elastomer composites allows:

1) Reducing loss of elastomeric composites;

2) To increase the productivity of the target product;

3) Reducing the formation of small particles in elastomeric composites.

References:

1. Makarov, I.M., Lokhin, V.M., eds. (2001). *Intellektual'nye sistemy avtomaticheskogo upravleniya. [Intelligent automatic control systems]*. Moscow: Fizmatlit, 576 p. (in Russian).
2. Omatu, S., Khalid, M., Yusof, R. (1995). *Neuro-Control and its applications*. London: Springer-Verlag, 255 p.
3. Terekhov, V.A., Yefimov, D.V., Tyukin, I.Y. (2002). *Neyrosetevye sistemy upravleniya. [Neural network control systems]*. Moscow: Vysshaya shkola, 183 p. (in Russian).
4. Yusupbekov, N.R., Muxitdinov, D.P., Bazarov, M.B., Xalilov, A.J. (2010). *Boshqarish sistemalarini kompyuterli modellashtirish asoslari*, 330 bet.
5. KHakimzyanov, G.S. (2014). *Matematicheskoe modelirovanie [Math modeling]*. Novosibirsk, 218 p. (in Russian).
6. Gershenfield, N. The nature of mathematical modeling, Cambridge University Press.
7. Yusupbekov, N.R., Muxitdinov, D.P. (2015). *Texnologik jarayonlarni modellashtirish va optimallashtirish asoslari*. T.: «Fan va texnologiya», 440 bet.
8. Wu Jian, Su Benlong, Liu Qiang and Wang Youshan (2014). Research on VulcanizationProcess Simulation of Butyl Rubber Based on A New Characterization Model of Curing Degree. *Progress in Rubber, Plastics and Recycling Technology*, 30(4).
9. Wang, D.H., Dong, Q., Jia, Y.X. (2015). Mathematical modeling and numerical simulation of the non-isothermal in-mold vulcanization of natural rubber. *Chin J Polym Sci*, 33, 395-403.
10. Yan, X. (2007). A numerical modeling of dynamic curing processof tire by finite element. *Polym J*, 39, 1001-1010.
11. Yau, Y.H., Wong, H.F., Ahmad, N. (2012). Numerical Heat Transfer Study for A Large Rubber Product. *International Journal of Heat and Mass Transfer*, 55, 2879-2888.
12. Tikhomirov, S.G., Pyatakov, Y.V., Karmanova, O.V., Maslov, A.A., Khaustov, I.A., Podval'nyi, S.L. (2018). A Technique Of Calculating The Kinetics Of The Process Of Nonisothermal Vulcanization Of Large Articles. *Chemical and Petroleum Engineering*, 53(9-10), 647-652.
13. Shigeru Nozu, Hiroaki Tsuji, Kenji Onishi. (2011). A Prediction Model for Rubber Curing Process. Heat Transfer-Engineering Applications, *InTech, Rijeka*, 151-170.
14. Rafei, M., Ghoreishy, M.H.R., Naderi, G. (2009). Development of an advanced computer simulation technique for the modeling of rubber curing process. *ComputMater Sci*, 47, 539-547.