

Ministry of Education and Science  
Russian Federation  
National Research Nuclear University MEPhI

---

**6th International conference**  
**“Problems of Mathematical Physics**  
**and Mathematical Modelling”**

**Book of abstracts**  
(Moscow, NRNU MEPhI, 25–27 May 2017)

Moscow, Russia

**УДК 51(06)+53(06)**  
**ББК 22.1г+22.3г**  
**I73**

**6th International conference “Problems of Mathematical Physics and Mathematical Modelling”: Books of abstracts** (Moscow, NRNU MEPhI, 25–27 May). / M.B. Kochanov.  
M.: Moscow, 2017. — 221 p.  
**ISBN 978-5-7262-2378-0**

The book contains abstracts of 6th International conference “Problems of Mathematical Physics and Mathematical Modelling”

The contributions are reproduced directly from the originals  
presented by the authors

**УДК 51(06)+53(06)**  
**ББК 22.1г+22.3г**

*ISBN 978-5-7262-2378-0*

© *National Research Nuclear University MEPhI, 2017*

Decision on publication 22.05.2017. Format 60x84 1/8.  
Quires 27,75. Circulation 120. Order №76.

*National Research Nuclear University MEPhI*  
*Printing house NRNU MEPhI*  
*115409, Moscow, Kashirskoe shosse, 31*

## Co-chairs

V.V. Kozlov, Member of the Russian Academy of Science, Russia

N.A. Kudryshov, Head of department of Applied Mathematics NRNU MEPhI, Russia

O.V. Nagornov, Head of department of Higher Mathematics of NRNU MEPhI, Russia

## Program committee

V.V. Kozlov, Member of the Russian Academy of Science, Russia

N.A. Kudryshov, Head of department of Applied Mathematics NRNU MEPhI, Russia

O.V. Nagornov, Head of department of Pure Mathematics of NRNU MEPhI, Russia

N. Pogorelov, University of Alabama in Huntsville, USA

A.V. Aksenov, Lomonosov Moscow State University, Russia

S.Yu. Misyurin, Director of Institute of Cyber Intelligence Systems NRNU MEPhI, Russia

V. Arakelyan, Institut National des Sciences Appliquées, France

P. Chardonnet, University of Savoie, France

Y. Efendiev, Director of Institute for Scientific Computation, Texas A&M University, USA

S.A. Kaschenko, Yaroslavl State University, Russia

A.V. Kryanev, NRNU MEPhI, Russia

R. Lazarov, Texas A&M University, USA

A.D. Polyinin, IPMech RAS, Russia

O.I. Vinogradova, Lomonosov Moscow State University, Russia

R. Conte, Condensed Matter Laboratory, CEA Saclay, France

P. Bedrikovetsky, University of Adelaide, Australia

<i>Avvakumov A.V., Strizhov V.F., Vabishchevich P.N., Vasilev A.O.</i> Modelling dynamic processes in a nuclear reactor by state change modal method.....	112
<i>Beskrovnaya A.A., Savyolova T.I.</i> Calculation of pole figures by functions on $S^2$ in $R^3$ that are projections from the canonical normal distribution on $SO(3)$ .....	114
<i>Brykalov S.M., Kryanev A.V.</i> Mathematical model comparing of the multi-level economics systems.....	116
<i>Bychkov P.S., Saifutdinov I.N.</i> Holographic Interferometry of Thin-walled Structure Distortion during the Stereolithography Process. ....	118
<i>Derenovskaya O.Y., Ivanov V.V., Ogorodnikova D.S.</i> $J/\psi \rightarrow e^+e^-$ decays reconstruction for 10 AGeV Au+Au collisions in the CBM experiment.....	120
<i>Divakov D.V., Malykh M.D., Sevastianov L.A., Nikolaev N.E.</i> Modeling the propagation of polarized light in a thin-film waveguide lens .....	122
<i>Druzhinina O.V., Sevastianov L.A., Vasilyev S.A., Vassilyeva D.G.</i> Lyapunov stability analysis for the generalized Kapitza pendulum .....	123
<i>Eferina E.G., Kulyabov D.S.</i> Implementation of diagram technique for statistical systems in Sympy .....	125
<i>Egorov A.A.</i> Influence of fluctuations of local orientation of nematic liquid crystal molecules on the coefficient of damping of waveguide modes .....	128
<i>Filatov S.V., Savyolova T.I.</i> About normal distribution on $SO(3)$ group in texture analysis.....	130
<i>Gubin S.A., Maklashova I.V., Mel'nikov I.N.</i> The molecular dynamics method as the technique for properties evaluation of shock-compressed copper.....	131
<i>Karimov A.R., Dementev A.A.</i> Collisionless relaxation of non-neutral Maxwellian plasmas .....	133
<i>Korotkov E.V.</i> Developing of mathematical approach for multi alignment of promoter sites and regions of splicing.....	134
<i>Kudinov A.V., Bogdanova Y.A., Gubin S.A.</i> Molecular dynamics simulation of thermodynamical properties of methane.....	136
<i>Kuksenok I.S.</i> Divergence of the wing in the supersonic gas flow and some equilibrium states .....	138
<i>Kukudzhanov K.V., Levitin A.L.</i> The healing of damage of metal under treatment high-energy pulsed electromagnetic field. ....	140
<i>Kulyabov D.S., Gevorkyan M.N., Demidova A.V., Korolkova A.V., Sevastianov L.A.</i> The construction of the SDE for modeling wind speed for wind power plants.....	141
<i>Makin V.S., Makin R.S.</i> Nonlinear mathematical model for spatial periods of micro- and nanogratings formation in framework of universal polariton model of laser-induced condensed matter damage.....	143
<i>Malykh M.D., Sevastianov L.A., Tyutyunnik A., Nikolaev N.E.</i> On the representation of Maxwell's equations in closed waveguides by the help of Helmholtz equations.....	145
<i>Manzhirrov A.V., Kazakov K.E.</i> Axisymmetric contact problem for a rigid punch and a coated foundation with rough surfaces.....	147
<i>Misyurin S.Y., Kreinin G.V.</i> Coordinated interaction of two hydraulic cylinders when moving large-sized objects .....	149
<i>Misyurin S.Y., Kreinin G.V.</i> Selecting the parameters of the power channel of the automated drive .....	150
<i>Misyurin S.Y., Kreinin G.V., Nelyubin A.P.</i> Dynamic design and control of a high-speed pneumatic jet actuator.....	151
<i>Misyurin S.Y., Nelyubin A.P.</i> Multicriteria adaptation principle on example of groups of mobile robots .....	152
<i>Murashkin E.V., Radayev Y.N.</i> A Thermomechanical Constitutive Law in Virtue of Thermodynamic Orthogonality .....	153
<i>Murashkin E.V., Radayev Y.N.</i> On Wave Analytical Solution of Micropolar Elasticity for a Cylinder .....	155
<i>Nor A.A., Korotkov E.V.</i> New method for searching for latent periodicity in poetic texts with insertions and deletions .....	158
<i>Parshin D.A., Manzhirrov A.V.</i> Quasistatic problems for piecewise-continuously growing solids with integral force conditions on surfaces expanding due to additional material influx.....	159
<i>Perelmuter M.N.</i> Application of the bridged crack model for evaluation of materials self-healing .....	162

<i>Rashchikov V.I., Shikanov A.E.</i> Computer simulation of small size neutron generators with magnetic insulation .....	164
<i>Savatorova V.L., Talonov A.V., Kossovich E.L.</i> Dispersion and anisotropy of elastic waves in fractured porous media.....	166
<i>Sumskoi S.I., Sverchkov A.M., Lisanov M.V.</i> Mathematical modeling of water hammer with cavitation.....	167
<i>Suvorova Y.M., Korotkov E.V.</i> Cluster analysis of <i>S.Cerevisiae</i> nucleosome binding sites.....	170
<i>Vasilyev S.A., Kolosova I.S.</i> The Boundary Value Problem for Relativistic Schrodinger Equation.....	171
<i>Velieva T.R., Korolkova A.V., Kulybov D.S., Zaryadov I.S.</i> An approach to invistigate the regions of self-oscillations.....	174
<i>Zagrebaev A.M., Trifonenkov A.V.</i> Application of thermal-hydraulic model of RBMK-type reactor fuel channel for correction of experiment-calculated values of power and coolant flow .....	176

## Section “Mathematical modelling”

<i>Barmenkov A.N., Barmenkov N.A.</i> About orthogonality of the single systems of special kind .....	179
<i>Baskakov A.V., Volkov N.P.</i> On the controllability of transition processes in problems of reactor dynamics .	180
<i>Baskakov, A.V., Volkov N.P.</i> On the controllability of the transition processes in problems of reactor dynamics .....	182
<i>Belendryasova E.G., Gani V.A.</i> Resonance phenomena in the $\varphi^8$ kinks scattering .....	184
<i>Dunin S.Z., Nagornov O.V.</i> Spontaneous evaporation of the acetone drop.....	186
<i>Ivanova T.M.</i> On the smoothing and consistency of data on pole figures .....	187
<i>Ivanova T.M., Serebryany V.N.</i> Simulation of complex magnesium alloy texture using the axial component fit method with central normal distributions .....	188
<i>Kamynin V., Bukharova T.</i> On an inverse problem for degenerate higher order parabolic equation with integral observation in time.....	189
<i>Konovalov Y.V.</i> Ice-tongue vibrations modelled by a full 3-D depth-integrated elastic model .....	191
<i>Kostin A.B., Sherstyukov V.B.</i> Calculation of functions of Rayleigh type for roots of the equation related to the spectral problem .....	193
<i>Leonov A.S., Sorokin V.N.</i> A posteriori error estimates in voice source recovery .....	194
<i>Lychev S.A., Koifman K.G.</i> Geometric Methods in the Theory of Structurally Inhomogeneous Bodies .....	196
<i>Lychev S.A., Lycheva T.N.</i> Structural Inhomogeneity in LbL Cylindrical Structures .....	198
<i>Murashkin E., Dats E., Klindukhov V.</i> Algorithm for Calculating the Elastic-Plastic Boundaries in the Thermal Stresses Theory Frameworks .....	201
<i>Nagornov O.V., Tyufin S.A., Trifonenkov V.P.</i> Reliability of the past surface temperature reconstruction methods .....	203
<i>Nikitaev V.G., Nagornov O.V., Pronichev A.N., Polyakov E.V., Dmitrieva V.V.</i> Study of the noise effect on texture characteristics of blood cells using mathematical model of microscopic images of nucleus of leukocytes. ....	205
<i>Orlovsky D.</i> Inverse problem for the equation with $n$ -times integrated semigroup.....	206
<i>Petrov S.V., Prostokishin V.M.</i> On Representation of Riesz-space-valued Functions by Fourier Series on Multiplicative Systems .....	208
<i>Rubinstein A.I.</i> On the Analog of the Bary–Stechkin Theorem of the Conjugate Functions for the Dyadic Group .....	210
<i>Sherstyukov V.B., Sumin E.V.</i> One method of calculating special sums composed by zeros of entire function.....	211
<i>Snezhin A.N., Vaskan I.Y., Prostokishin V.M.</i> Information-situational maps: mathematical models and application in modern training complexes .....	213
<i>Soloviev V.V., Tkachenko D.S.</i> On solvability for inverse problems of compact support source determination for heat equation.....	215
<i>Suchkov M.V., Trifonenkov V.P.</i> On the Localization Principle for Laplace Operator with Piecewise Constant Coefficient in Domains without Discontinuity Points.....	217

## **An approach to investigate the regions of self-oscillations**

T.R. Velieva<sup>1,a)</sup>, A.V. Korolkova<sup>1,b)</sup>, D.S. Kulybov<sup>1,c)</sup>, I.S. Zaryadov<sup>1</sup>

<sup>1</sup>*Peoples' Friendship University of Russia (RUDN University)*

In systems with control, there is such a negative phenomenon as global synchronization, which is expressed in the form of self-oscillations. To eliminate this phenomenon, it is necessary to investigate the effect of system parameters on characteristics. As an implementation of the threshold control system, we investigate the active traffic control module RED, and the cause of the self-oscillation is the type of the reset function. In this paper we consider the application of the block-linear approach to control theory and the application of harmonic linearization.

The work is partially supported by RFBR grants No's 15-07-08795 and 16-07-00556. Also the publication was financially supported by the Ministry of Education and Science of the Russian Federation (the Agreement No 02.A03.21.0008).

## **1 Application of the method of harmonic linearization**

To describe the RED algorithm we will use the following continuous model (see [1, 2, 3]) with some simplifying assumptions: the model is written in the moments; the model describes only the phase of congestion avoidance for TCP Reno protocol; in the model the drop is considered only after reception of 3 consistent ACK confirmations.

The method of harmonic linearization is an approximate method. The harmonic linearization differs from the common method of linearization and allows to explore the basic properties of nonlinear systems.

The method of harmonic linearization is used for systems of a certain structure. The system consists of linear part  $H_l$  and the nonlinear part, which is set by function  $f(x)$ . It is generally considered a static nonlinear element.

In a block-linear approach to control theory the original nonlinear system is linearized and divided into blocks. The blocks are characterized by a transfer function, which connects input and output values. The linearization method is described in the article [2]. We obtain a linearized system:

$$\begin{cases} \delta \dot{W}(t) = \frac{\delta L_W}{\delta W}|_f \delta W(t) + \frac{\delta L_W}{\delta W_T}|_f \delta W(t - T_f) + \frac{\delta L_W}{\delta Q}|_f \delta Q(t) + \frac{\delta L_W}{\delta p}|_f \delta p(t - T_f) = \\ = -\frac{N}{CT_f^2}(\delta W(t) + \delta W(t - T_f)) - \frac{C^2 T_f}{2N^2} \delta p(t - T_f); \\ \delta \dot{Q}(t) = \frac{\delta L_Q}{\delta W}|_f \delta W(t) + \frac{\delta L_Q}{\delta Q}|_f \delta Q(t) = \frac{N}{T_f} \delta W(t) - \frac{1}{T_f} \delta Q(t). \\ \delta \dot{\hat{Q}}(t) = \frac{\delta L_{\hat{Q}}}{\delta Q}|_f \delta \hat{Q}(t) + \frac{\delta L_{\hat{Q}}}{\delta Q}|_f \delta Q(t) = -w_q C \delta \hat{Q}(t) + w_q C \delta Q(t). \end{cases} \quad (1)$$

After we linearize the drop function. It will take the following form:

$$\delta p(s) = P_{\text{RED}} \frac{1}{1 + \frac{s}{w_q C}} \delta Q(s). \quad (2)$$

The block representation of the linearized RED model (Fig. 1) is constructed.

---

<sup>a)</sup>Email: velieva\_tr@rudn.university

<sup>b)</sup>Email: korolkova\_av@rudn.university

<sup>c)</sup>Email: kulyabov\_ds@rudn.university

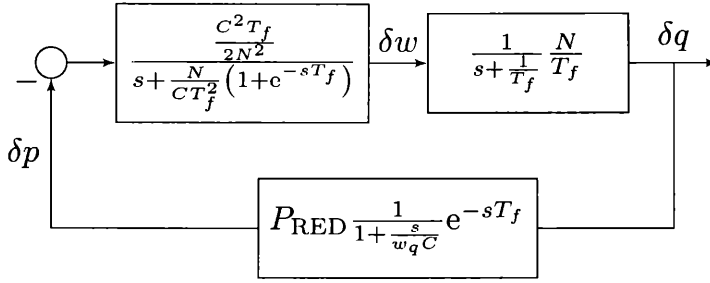


Fig. 1: Block representation of the linearized RED model

To determine the region of self-oscillations, we use the Routh-Hurwitz criterion, and to determine the self-oscillation parameters, use Mikhailov's criterion. This criterion is an algebraic criterion of stability.

The transfer function of the conservative system has the form

$$H_c(s) = \frac{H_l(s)}{1 + H_l(s)H_{nl}(s)} := \frac{P_n(s)}{P_d(s)}. \quad (3)$$

The equation  $P_d(s) = 0$  is the characteristic equation of the system. It can be present in the polynomial form:

$$P_d(s) := a_0 s^n + a_1 s^{n-1} + \dots + a_n. \quad (4)$$

From the coefficients of the characteristic equation one can construct Hurwitz determinant  $\Delta$ .

By the Hurwitz criterion, in order for the dynamical system to be stable, it is necessary and sufficient that all  $n$  principal diagonal minors of the Hurwitz determinant be positive, provided that  $a_0 > 0$ . These minors are called Hurwitz determinants. The system is located on the boundary of the oscillatory system, if  $\Delta_{n-1} = 0$ . In this case, there are auto-oscillations. Consider the criterion of Mikhailov.

Let us write the characteristic equation of the conservative system (3) with respect of  $s \rightarrow \delta_t \rightarrow i\omega$ :

$$P_d(i\omega) = 0. \quad (5)$$

In addition, if one explicitly allocates real and complex parts, then the equation (5) can be written in the following form:

$$\Re P_d(i\omega) = 0, \quad \Im P_d(i\omega) = 0. \quad (6)$$

Thus, the parameters of self-oscillations can be determined from equation (6). Let us compute the coefficients of harmonic linearization  $\kappa(a)$  and  $\kappa'(a)$  (7)

$$\kappa(A) = \frac{4}{A\pi} \frac{p_{\max}}{Q_{\max} - Q_{\min}} \left( \sqrt{1 - \frac{Q_{\min}^2}{A^2}} - \sqrt{1 - \frac{Q_{\max}^2}{A^2}} \right); \quad (7)$$

$$\kappa'(A) = \frac{4}{A\pi} \frac{p_{\max}}{Q_{\max} - Q_{\min}} \frac{Q_{\max} - Q_{\min}}{A} = \frac{4p_{\max}}{A^2\pi}. \quad (8)$$

Let's write the balance equation between frequency and amplitude:

$$\begin{aligned} \frac{1}{I\omega + \frac{N}{CT_f^2}(1 + E^{-I\omega T_f})} \frac{1}{I\omega + \frac{1}{T_f}} \frac{1}{1 + \frac{I\omega}{w_q C}} \frac{C^2}{2N} E^{-I\omega T_f} = \\ = -\frac{A\pi}{4p_{\max}} \left[ \frac{1}{Q_{\max} - Q_{\min}} \left( \sqrt{1 - \frac{Q_{\min}^2}{A^2}} - \sqrt{1 - \frac{Q_{\max}^2}{A^2}} \right) + I \frac{1}{A} \right]^{-1}. \end{aligned} \quad (9)$$

In this paper, harmonic linearization was used to determine the region of origin of self-oscillations and their parameters. The obtained values are verified using the simulation tool NS2.

## References

- [1] Misra Vishal, Gong Wei-Bo, Towsley Don. Stochastic Differential Equation Modeling and Analysis of TCP-Window Size Behavior // Proceedings of PERFORMANCE. — 1999. — Vol. 99.
- [2] Holot C. V. V., Misra Vishal, Towsley Don. A Control Theoretic Analysis of RED // Proceedings IEEE INFOCOM 2001. Conference on Computer Communications. Twentieth Annual Joint Conference of the IEEE Computer and Communications Society (Cat. No. 01CH37213). — Vol. 3. — IEEE, 2001. — P. 1510–1519. %newblock Combinatorial and Operator Approaches to RED Modeling // Mathematical Modelling and Geometry. — 2015. — Vol. 3, no. 3. — P. 1–18.
- [3] Korolkova Anna Vladislavovna, Velieva Tatyana Refatovna, Abaev Pavel Avanesovich et al. Hybrid Simulation Of Active Traffic Management // Proceedings 30th European Conference on Modelling and Simulation. — 2016. — jun. — P. 685–691.

## **Application of thermal-hydraulic model of RBMK-type reactor fuel channel for correction of experiment-calculated values of power and coolant flow**

A.M. Zagrebaev<sup>1,a)</sup>, A.V. Trifonenkov<sup>1,b)</sup>

<sup>1</sup>*National Research Nuclear University MEPhI (Moscow Engineering Physics Institute)*

The effectiveness and the security of RBMK-type reactor operation depends on the accuracy of the control over reactor's parameters and their limitations. The processing of operational parameters archive helps to adjust different mathematical models and significantly widen their field of use. Pressure differential between common pressure header and steam separator is the sum of calculated pressure differential and friction loss on flow control valve. There is known mathematical software, which allows to adapt such model for each fuel channel using the archive. In this research it is suggested not to replace the regular mechanism with such approach, but to use the adapted mathematical model to calculate corrected values of power and flow, which were measured by regular means. Mathematical expressions and procedures for such approach are given.

The effectiveness and the security of RBMK-type reactor operation depends on the accuracy of the control over reactor's parameters and their limitations. Two of the most important parameters are the coolant flow through fuel channel and the energy emission, or power of the channel. Currently used means of control and algorithms of information processing surely give a reliable solution to the problem [1]. Nevertheless, research of new methods of accuracy increase for control systems is always a problem of interest. At present, such methods may involve using an archive of nuclear reactor operational parameters for a long period of time. In particular, the processing of operational parameters archive helps to adjust different mathematical models and

---

<sup>a)</sup>Email: AMZagrebaev@mephi.ru

<sup>b)</sup>Email: AVTrifonenkov@mephi.ru