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PERSONAGE IN SCIENCE

Academician V.M. Matrosov

In Memoriam

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This paper is dedicated to the memory of V.M. Matrosov in recognition of the significance of his results in the development of stability theory, his remarkable and versatile talent in research on dynamic systems, as well as the novelty and depth of his contribution to mathematics and world science.

1 Short Biography

V.M. MATROSOV was born on May 8, 1932 in Shipunovo village on the Altay, USSR (now Russian Federation). In 1956, he graduated with distinction from the Kazan Aviation Institute (KAI), the Aircraft Engineering Faculty, and entered the post-graduate studies under the supervision of Professor P.A. Kuzmin at the Chair of Theoretical Mechanics of KAI. He began working at the Institute as a junior professor and advanced to the position of an assistant professor of the Chair of Theoretical Mechanics. In 1959, Matrosov defended his Candidate Thesis (PhD) on the stability of gyroscopic systems. In 1968, Matrosov defended his Doctoral Thesis on the development of new methods of Lyapunov functions in the stability theory of motion. In the same year he became the Head of the Chair of Mathematics, and in 1972 he founded the Chair of Cybernetics which was training mainly the specialists in applied mathematics. At the same time he ran research laboratory at KAI where he carried out his first investigations in applied mathematics.

In 1975, Matrosov and several of his associates were invited by academician G.I. Marchuk, the president of the Siberian Division of the Academy of Sciences of USSR, to move to Irkutsk with the purpose of founding a new academic institute. The institute was formed and Matrosov was its director-organizer.

In 1976, Matrosov was elected the corresponding member, and in 1987 he became the member of the Academy of Sciences of USSR. In 1991, he established and headed the

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Moscow Division of the Institute of Transport Problems of the Academy of Sciences of USSR. In 1996, he founded the Research Center for Stability and Nonlinear Dynamics Research at the A.A. Blagonravov Institute of Machine Building of the Russian Academy of Sciences (RAS) and was at its head until the end of his life (on April 17, 2011). While doing scientific research Matrosov was vigorously engaged in pedagogical activity. He was a professor of Sociology Faculty of M.V. Lomonosov Moscow State University (1998–2003) and held the Chair of Mathematical Cybernetics at Moscow Aviation Institute (2000–2007).

Matrosov passed away on April 17, 2011, at the age of 79. He is survived by his wife Nina, son Ivan, daughter Claudia, and grand children Ivan and Alexander.

2 Scientific Work

2.1 Gyroscopic systems

At the beginning of his academic career Matrosov focused on stability of gyroscopic systems. Using refined modifications of Lyapunov theorems he managed to establish a series of important criteria of equilibrium stability and instability, which are now applied in the theory of gyroscopic and electromechanical systems.

At that time, he also carried out investigations on stability of solutions to nonautonomous differential equations [1]. He showed impossibility of extending to these equations the known Barbashin–Krasovsky theorem on asymptotic stability of motion in terms of Lyapunov function with sign-constant derivative. The obtained results have been applied in many areas of modern nonlinear dynamics.

2.2 Vector Lyapunov functions

Matrosov's investigations on development of the method of Lyapunov functions proved to be of importance for weakening the requirements on Lyapunov functions. At one and the same time as R. Bellman (USA) he introduced the notion of Vector Lyapunov Function (VLF) [2] satisfying the system of differential inequalities of Chaplygin-Wazhevsky type. Matrosov formulated first theorems on stability using VLF [2-4], which provided general criteria for stability of motion. The characteristic features of these results are that the requirements placed on classical Lyapunov functions are replaced by a totality of less strict conditions imposed on some components of VLF.

The new idea of VLF was further developed and applied by numerous researchers in USSR (in present-day Russia, Ukraine, and Kazakhstan), USA, France, Italy, Belgium, Japan, etc. In his turn, Matrosov conducted a profound and versatile investigation of this idea for ordinary differential equations in Banach space with discontinuous unbounded operators (see [5-7] and bibliography therein).

2.3 Mathematical theory of systems

In 1970, Matrosov and his collaborators initiated new models in mathematical system theory (system of processes, generalized structures, etc.). Having analyzed thoroughly the structure of proofs of comparison theorems for differential equations, Matrosov established and proved, in a unique algorithmic form, the principle of comparison for deduction of comparison theorems on dynamic properties of systems of processes [8].

The new results paved the way for comparison theorems involving VLF to be established algorithmically by formulas of the considered dynamic properties of a wide class of systems (see [9–11] and bibliography therein). The development of these algorithms and their computer realizations have provided many new and useful results for study of various models in dynamical systems and control theory [12, 13].

2.4 Methods of construction of vector Lyapunov functions

Matrosov and his associates [14–16] developed three groups of methods of VLF construction. The first group embraces the methods associated with exact exponential estimates based on decomposition-aggregation of multi-interconnected systems. This group also includes a combined method representing a finite iteration process of complex system decomposition and VLF refinement which is associated with the hierarchy of subsystems and VLF as well.

The second group of methods consists of decompositions and further estimation of aggregation of multi-interconnected systems with the application of VLF, which is related to the F.N. Baileys approach (1966).

And finally, the third group of methods is a construction of sub-linear VLF. This construction has turned out to be the most efficient in applications.

2.5 Dynamics and control of aerospace structures

Among numerous applications of Matrosov's scientific results to real engineering systems the investigations of dynamics and control of aerospace structures were of particular importance. The employment of finite iteration process of VLF construction resulted in significant applications. Among them, stability investigations of the first Soviet stratospheric observatory (1975) and orbital astronomic observatory with sub-millimeter telescope BST-1 installed in the space station Salut-6 (1977), which were used successfully for the investigations of thin structure of photosphere of the Sun and other space objects. On the basis of VLF method and other methods of nonlinear analysis these and many other problems of dynamics and control have been studied (see [15, 17–22] and bibliography therein). Under academic supervision of Matrosov a unique complex of packages of applied programs for BESM-6, MVK Elbrus-1K2 and ES EVM was developed to solve the problems of nonlinear dynamics and control theory. This research carried out by Matrosov, his colleagues and research assistants allowed the method of VLF to evolve into a practical tool for scientific and engineering calculations of system dynamics. For the series of investigations on the development of VLF method Matrosov and his associates were given the State Prize in the field of science and technology in 1984.

2.6 Research on multi-package methods

In the late 1970s Matrosov initiated research on multi-package methods of solving the problems of modeling, analysis and optimization of complex systems [23]. Such research was induced by the results on intellectualization of computer systems in terms of the methods of logical generation of alternative solutions to the problems (including computation plans) and multi-criterion estimation of solution preferability. In addition to the logical-and-heuristic approach to the automation of synthesis of theorems of the type of VLF method theorems [9, 12] the other methods were used. They are: the methods of solution of logical equations, automation of logical deduction and automatic proof of

theorems, as well as the methods of multi-criterion decision-making. At that period of time a concept and components of intellectualization of a research prototype of the software system EVROLOG-1 with professional artificial intelligence [24] were developed. With Matrosov as its director, the Irkutsk Computing Center of the Siberian Division of Academy of Sciences of USSR became a leader in constructing software for automation of design and research of control systems for complex moving objects [25–27].

2.7 Mathematical modeling of national economy

As early as the end of the 1960s Matrosov extended his interests to the electric power industry and other fields of national economy, as well as the economic, medical, biological and other systems. In particular, the method of VLF was used for the analysis of electric power systems, immunological models, etc. Under Matrosov's supervision a wide range of problems were studied in creating an automation system for solution of problems in modeling and optimization of the fuel and energy complex of USSR. Experimental automation systems were worked out for modeling the development of regional areas [28, 29] including branches of industry, medicine and ecological stability and safe development of these regions. Investigations were carried out on estimation of after-effects of possible technological disasters at oil and chemical facilities. In the 1990s Matrosov arranged the work on creating a social, ecological and economical model of interactions of Russian regional areas allowing for the population migration, production and redistribution of income.

2.8 Problems of global security and stable development

Motivated by the well-known problem of reduction of the strategic offensive weapons, Matrosov initiated investigations of stability of military strategic balance (MSB) of a multi-polar world. In this regard a program system was developed allowing for variation of parameters and characteristics of the weapons and construction of areas of MSB for different scenarios of development of the strategic weapons of Russia and USA. An approach was proposed for the analysis of stable weapon dynamics and stability of MSB based on the method of comparison using VLF for estimating the strategy of defense sufficiency as well as other strategies [30–33].

As early as the 1980s, Matrosov deeply feeled that the popular model of a consumer society, which was universally promoted, is futile. Such a society may cause irreversible changes in the ecosphere and, finally, lead to a global disaster. Under Matrosov's supervision a large body of work was carried out on modifications of the well known model of world dynamics by G. Forrester (USA). Together with Professor A. Onishi (Japan) Matrosov proposed a concept of the international project "Methods and Program Tools for the Analysis of Global Development Stability" (1991).

3 Matrosov's Public Activity

Apart from his intensive scientific activity Matrosov took an active role in public activity. In particular, for several years he participated in the projects realized by the V.I. Vernadsky Foundation and worked at the Commission on Problems of Sustainable Development of The State Duma (Council) of Federal Assembly of The Russian Federation. As the Head of the Center for Modeling of the Sustainable Development of Society at the

Institute of Social and Political Investigations of RAS (1984–2001), Matrosov delivered lectures on stable development of society to the students of Moscow State University [34].

This sketch of Matrosov's accomplishments does not exhaust by any means his versatile and fruitful scientific, professional and public activity. He was a great scientist and a gifted organizer of scientific projects and pursuits. His untethered energy and ability not to spare himself in what he was doing have always impressed those who used to know him closely. His absolute devotion to science has served as an example to others. Matrosov's kindness, collegiality, generosity of a scholar and superb command of the knowledge in his field guaranteed success of his work and work of his collaborators.

Matrosov's organizational, pedagogical and public activities were honored by many state awards and scientific prizes. The abundant scientific legacy of academician Matrosov produced a profound intellectual and humanitarian effect on his readers and had a significant influence on the future generations of researchers.

4 List of Monographs and Books by V.M. Matrosov

[A] Matrosov, V.M. *The Method of Vector Lyapunov Functions: Analysis of Dynamical Properties of Nonlinear Systems.* Fizmatlit, Moscow, 2001. [Russian]

[B] Matrosov, V.M., Anapolsky, L.Yu. and Vassilyev, S.N. *The Method of Comparison in Mathematical System Theory.* Nauka, Novosibirsk, 1980. [Russian]

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[H] *A New Paradigm for the Development of Russia in the 21st Century. Complex Investigations of Problems of Sustainable Development: Ideas and Results.* (Eds. V.A. Koptyug, V.M. Matrosov, V.K. Levashov). Academia, Moscow, 1999. [Russian]

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5 List of the Matrosov Selected Papers

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[7] Matrosov, V.M. *The Method of Vector Lyapunov Functions: Analysis of Dynamical Properties of Nonlinear Systems.* Fizmatlit, Moscow, 2001. [Russian]

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