Brief information about the project

Name of the project	AP19677384 “Development and research of the dynamics of a gas centrifuge on magnetic bearings with nonlinear characteristics and a control system”.
Relevance	Modern gas centrifuges used in the nuclear industry for uranium enrichment are just one of many examples of non-linear magnetic bearing rotor systems. Like any dynamic systems, rotary machines are subject to various kinds of vibrations. Due to the non-linear dependences of magnetic forces, magnetic bearings are non-linear supports. The idea of the project is to develop a generalized dynamic model of a nonlinear rotor system on magnetic bearings and to development an optimal control algorithm that provides a low level of system vibrations, on the basis of which a new gas centrifuge design will be created.
Purpose	Development of a generalized dynamic model of a nonlinear rotor system on magnetic bearings and a method for its study. Development of a control algorithm for the "rotor-magnetic bearings-foundation" system, providing a low level of vibration. Development of a software package. Creation of a new design of a gas centrifuge.
Objectives	To achieve the formulated goal, the following tasks are solved: • development of a dynamic model of the "rotor-magnetic bearings-foundation” system to study the oscillations of the system; • development of a method for studying the natural nonlinear oscillations of the rotor system; • determination of criical frequencies and calculation of amplitudes of natural oscillations; • development of a method for studying forced nonlinear oscillations of the system; • determination of resonant frequencies and calculation of amplitudes of forced oscillations; • carrying out parametric analysis; • development of a control algorithm to provide a low level of natural and forced oscilations based on feedback methods, such aз Extended Kalman Filter (EKF), $H\infty$ - control (in case of random vibrations), Linear-Quadratic Regulator (LQR) for the nonlinear system, theory of Lyapunov functions; • development of automated modeling procedures; • a comparative analysis with the experimental results of other authors and with similar theoretical analytical and numerical calculations for the approbation and verification of the developed methods, control algorithm and automated procedures; • designing of a new high-performance and dynamically more stable gas centrfuge by taking into account the mobilty of the foundation and the nonlinearity of the supports.

Expected and achieved results	The tasks of the nuclear industry taking into account its prospects and minimal damage to the environment during normal operation have always been of particular importance in the economy of any country. At the moment, there are about 440 nuclear power plants operating on uranium with an enrichment index of ~3-5%, which produce approximately 20% of the world's electricity. This indicator, due to environmental pollution by hydrocarbons, will only grow. At present, gas centrifuges have the highest enrichment factor. Increasing the indicator of the kinetic enrichment technology by selecting the optimal rigidity and inertial characteristics based on the analytical parametric analysis of the developed and solved generalized nonlinear dynamic model is economically more favorable than other enrichment technologies such as laser isotope separation methods, for example, MLIS, CRISLA, SILEX, AVLIS, etc. The expected social and economic effect from the results of the project is provided by the possibility of increasing the enrichment rate of gas centrifuges (for example, the actual separation factors of gas diffusion plants is ~ 1.001, for gas centrifuges ~ 1.09), which will bring huge economic profit, in addition, the creation and operation of gas centrifuges in Kazakhstan will contribute to solution of such problems as, for example, environmental pollution, energy shortages, such social problems as creating new jobs, etc.
Research team members with their identifiers (Scopus Author ID, Researcher ID, ORCID, if available) and links to relevant profiles	1. Kydyrbekuly Almatbek Balgabekovich, DSc., H – 3, ORCID: 0000-0002-8345-7334, Scopus author ID: 55779558700. 2. Julius Kaplunov, DSc., prof. (UK, Keele University), H – 26; ORCID: 0000-0001-7505-4546, Scopus Author ID: 6701814679. 3. Rakhmetolla Abdizhalel, PhD, acc.prof., SRI of Mathematics and Mechanics of Farabi University, Lead Research Scientist. 4. Khajiyeva Lelya, DSc., prof., H – 5, ORCID: 0000-0002-2565-3409, Scopus author ID: 55779888800. 5. Ibrayev Gulama-Garip Alisher, PhD, H – 3; ORCID: 0000-0001-5000-0023, Scopus Author ID: 57190969416. 6. Zhengis Beksultan, Undergraduate Student of Farabi University. 7. Efendiyev Said, PhD candidate of Farabi University. 8. Rayeva Kuralay, SRI of Mathematics and Mechanics of Farabi University, Research Scientist.
List of publications with links to them	Kydyrbekuly A., Zhauyt A., Ibrayev G. G. A. Parametric Analysis of Nonlinear Oscillations of the “Rotor–Weakly Conductive Viscous Fluid–Foundation” System under the Action of a Magnetic Field //Applied Sciences. – 2023. – V. 13. – No. 21. – P. 12089. **(Scopus, Процентиль: 75%, SJR = 0.492, CiteScore = 4.5, Q2, DOI: https://doi.org/10.3390/app132112089).**

Patents	-