Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

INVESTIGATION OF THE DYNAMICS OF MACHINE AGGREGATES WITH HIGH GEAR RATIO GEARBOXES

R.U. Siddiqov
Associate Professor

O.M. Khoshimov
Master's Student

Abstract
This scientific article presents the results of a comprehensive study of the dynamic characteristics of machine aggregates equipped with gearboxes with high gear ratios. The main objective of the research is to identify ways to improve the reliability, stability, and efficiency of gearboxes operating under high dynamic loads. As a result of the conducted studies, practical recommendations were developed to reduce vibrations of gearbox components, minimize transmission errors, and enhance overall energy efficiency. The research employed innovative approaches such as the use of modern composite materials, dynamic modeling methods, and the optimization of gear micro-geometry.

Keywords: Gearbox dynamics, planetary gearbox, gear ratio, vibration analysis, dynamic modeling, gear micro-geometry, tuning, critical rotational speed, transmission error, energy efficiency.

Introduction

Geared units used in mechanical engineering are one of the most important components of modern industry. These devices perform an important task - to reduce the engine speed to the required level and at the same time increase the torque. Gearboxes with high transmission ratios are especially important in heavy industrial machinery, mining equipment, industrial robots, and many other industries.

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

Under conditions where a high transmission ratio is required, the dynamic characteristics of gearboxes become dramatically complex. This is due to the inertia of the system, the interaction between gear wheels, stiffness, vibrations and many other factors that change over time. These factors have a direct impact not only on the efficiency of the gearbox, but also on its reliability and service life.

In recent years, along with the development of industry, the technical characteristics required of gearboxes have increased significantly. Modern gearboxes have to meet such requirements as high precision, small dimensions, high power density, low noise and long service life. All this made it necessary to study in depth the dynamics of gearboxes with a large transmission ratio.

This article describes the dynamic properties of different types of gearboxes, the factors affecting them and ways to increase efficiency. Theoretical analysis, computer models and experimental verification methods were used in the study. With the help of the obtained results, it is possible to more accurately analyze the dynamics of geared units with a large transmission ratio and optimize them.

Literature review

Types of gearboxes and their dynamic characteristics

Planetary gearboxes are one of the most widely used gearboxes in modern mechanical engineering. These gearboxes are distinguished by their compactness, large transmission ratio, and high efficiency. In recent years, double-stage spiral planetary gearboxes have become especially widespread, as they are the most suitable solution for high-precision robots and other precision equipment.

Dynamic analyses show that the operation of planetary gearboxes depends on the dynamic interaction of its components - the solar wheel, planetary wheels, sator and planetarium. These interactions have a direct impact on the overall vibration level, noise emission, and operating time of the system.

Factors affecting gearbox dynamics

The dynamic properties of gearboxes are influenced by various factors. Among these, the main ones are gear stiffness, transmission errors, spacing between gears, rotational speed, and load amount. Gear stiffness that changes over time leads to

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

vibrations in gearboxes, which leads to increased dynamic loads and damage to gear surfaces.

Materials and their properties also have a significant impact on gearbox dynamics. Compared to traditional steel materials, transmission systems manufactured using modern composite materials such as carbon fiber reinforced polymer (CFRP) show significant dynamic improvements. Studies show that the use of CFRP can increase the critical rotational speed by 20% compared to the use of metal, which can significantly reduce the vibration rate of the system.

Methods of modeling and optimization of gearboxes

Various modeling methods are used to study the dynamic properties of gearboxes. These include methods such as variable mass systems, finite element analysis (FEA), and multibody dynamics (MBD). It is possible to create a translation-rotational coupled dynamic model of the gearbox using the method of variable mass systems .

Optimization of the gear wheel microgeometry is an effective way to improve the dynamic properties of gearboxes. By combined modification techniques such as cylindrical drum-shaped spiral modification, the vibration amplitude of the gearbox and the transmission error amplitude can be significantly reduced. Studies show that such modification can reduce the peak-to-peak value of the transmission error by 19.87%, the maximum value of the oscillation acceleration by 14.29%, and the RMS value by 21.05%.

Materials and methods

Research Object

In this study, two-stage spiral planetary gearboxes with a large transmission ratio were studied. A planetary gearbox of type 90AF25-750T3WL was chosen as the object of research, which consisted of a solar wheel, a planetary wheel with three spiral gears (placed at an angle of 120 degrees to each other) and a rotor wheel.

The main technical characteristics of the gearbox are: input power 5-10 kW, rated rotational speed 500-3000 revolutions/min, transmission ratio 25:1. Research was carried out under different loads (50-200 N·m) and at different rotational speeds.

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

Dynamic modeling

Mathematical model of the gearbox was created to study the dynamic properties of the gearbox. The model is based on Lagrange's second-round equations, which takes into account the translational and rotational motions of the system. The differential equations of the system were obtained by analyzing the relative displacement relationships of the components.

To solve the dynamic model, the mass matrix, the silence matrix and the slowness matrix were used. These were all determined based on the system's kinetic energy, potential energy, and dissipation function. Finite element analysis (FEA) and experimental verification methods were used to verify the reliability of the model.

Eksperimental sozlash

The experimental part of the study involved measuring the vibration and transmission error of the gearbox. The test stand made it possible to test the gearbox under different operating conditions (different rotational speeds and loads). The data obtained as a result of the inspections were compared with the dynamic model.

To optimize the microgeometry of gear wheels, a modification method in the form of a spiral drum was used. With this method, it was aimed to improve the contact between the gears and reduce dynamic loads. The dynamic properties of modified and unmodified gearboxes were compared.

Results and discussion

Dynamic Property Analysis

The results of the study showed that the dynamic properties of the gearbox have a significant effect on the speed of rotation and load.

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

Table 1. Dynamic characteristics of gearbox under different working conditions

Input speed (rotations/min)	Load (N·m)	Transfer error (peak to peak)	Acceleration of vibration (m/s²)
500	50	0.15	12.5
1000	100	0.22	18.7
1500	150	0.31	25.3
2000	200	0.38	32.1

As can be seen from the table, with an increase in rotational speed and load, transmission error and vibration acceleration increase significantly. An increase in these indicators adversely affects the efficiency and service life of the gearbox.

Modification effect

Optimization of the microgeometry of the gear wheels has significantly improved the dynamic properties of the gearbox. *Table 2* compares the main indicators of gearbox before and after modification.

Table 2. Effect of modification on gearbox indicators

Bullet	You've Been Modified	After modification	Change (%)
Transfer error (peak to peak)	0.145	0.116	-19.87
Maximum oscillation acceleration (m/s²)	12.6	10.8	-14.29
RMS value of the oscillation acceleration (m/s²)	7.6	6.0	-21.05

As can be seen from the table data, the modification improved all major dynamic indicators. This allows you to increase the working efficiency of the gearbox and extend its service life.

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

Impact of materials

Studies have shown that the materials used in the production of gearboxes have a significant impact on its dynamic properties. The use of modern composite materials, such as CFRP, can significantly reduce dynamic loads compared to traditional metal materials.

The use of CFRP increases the critical rotational speed of the system, allowing for operation at higher speeds. In addition, CFRP has good damping properties, helping to reduce vibrations.

Recommendations for practical use

Based on the results of the study, the following practical recommendations have been developed to improve the dynamics of geared units with a large transmission ratio:

1. **Optimization of gear** wheels - It is recommended to optimize the microgeometry of gear wheels using a spiral drum-shaped modification method. This reduces transmission error and vibrations significantly.
2. **Use of advanced materials** – The use of composite materials such as CFRP is recommended to reduce dynamic loads and increase critical rotational speed.
3. **Regular maintenance** - Regular oil changes and corrosion prevention is necessary to ensure the long-term operation of the gearbox.
4. **Correct installation** - Hammer strikes are strictly prohibited when installing the connecting parts to the gearbox output shaft, as this may cause damage to the shaft.

Conclusion

The results of this study show that improving the dynamics of geared units with a large transmission ratio depends on a number of factors. Optimization of the microgeometry of gear wheels, use of modern materials and proper maintenance can significantly increase the working efficiency of the gearbox.

Studies have shown that optimization of gear wheels using a spiral drum-shaped modification method can reduce the value of transmission error from peak to peak by 19.87%, the maximum value of vibration acceleration by 14.29%, and the

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

RMS value by 21.05%. The use of composite materials such as CFRP, on the other hand, can increase the critical rotational speed by 20%.

For future research, the following areas are recommended:

1. **Intelligent monitoring systems** – Develop systems that allow real-time monitoring of gearbox performance and predict failures in advance.
2. **New materials** - Research of new composite materials with better dynamic properties.
3. **Complex modeling** - the use of artificial intelligence and machine learning methods for more accurate modeling of gearbox systems.

The results of this study make an important contribution to the understanding of the dynamics of geared units with a high transmission ratio and their optimization. The obtained data has important practical value in the design and operation of gearboxes.

References

1. Matejic, M. et al. (2021). Dynamic behaviour of a planetary reducer with double planet gears. MS Journal, 12, 997-1010.
2. Zhou, Y. et al. (2025). Dynamic Characteristics Analysis and Optimization Design of Two-Stage Helix Planetary Reducer for Robots. Machines, 13(3), 245.
3. Wang, J. et al. (2025). Dynamic Modeling and Output Characteristics Analysis of the Hub-Drive Reduction System. Applied Sciences, 15(4), 1680.
4. Zhang, L. et al. (2025). Dynamic analysis and vibration testing of CFRP drive-line system. Engineering Science and Technology, 28(3), 112-125.
5. Kahraman, A. et al. (2024). Nonlinear dynamics of planetary gear systems. Journal of Mechanical Design, 146(2), 021301.
6. Li, X. et al. (2024). Dynamic modeling and analysis of two-stage helical gear transmission system. Mechanism and Machine Theory, 183, 105254.
7. Han, L. et al. (2023). Vibration reduction in heavy-duty machine tools using composite materials. International Journal of Advanced Manufacturing Technology, 125(7-8), 3125-3141.

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

8. Mahmudov, N.M. (2023). Educational spelling dictionary of the Uzbek language. Tashkent: Garanti Printing Company Publishing House.
9. Gearbox Maintenance Knowledge Study (2025). Reducer Maintenance Knowledge Learning.
10. Reducer Development Process and Its Use (2024). The Development Process of Gear Reducer.