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The Ukrainian Scientific and Practical Conference "Scientific Research Methodology – 2024"

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MODELING AND DEVELOPMENT OF A SYSTEM FOR NON-CONTACT MEASUREMENT OF MECHANICAL CHARACTERISTICS OF THE ELECTRIC DRIVE

Abstract. *This study focuses on the development and simulation of a contactless sensor system for measuring mechanical parameters of electric drives. The research involves comparing various sensor designs, constructing mathematical models, and conducting simulations to evaluate the sensor's performance and its impact on the overall system. The work demonstrates that the newly developed sensor surpasses traditional methods in terms of accuracy and reliability, particularly in industrial applications requiring precise torque control.*

Key words: *electric drive, torque control, contactless sensor, magnetic-elastic sensors, mathematical modeling, ANSYS Maxwell, MATLAB Simulink.*

Introduction. Modern industrial processes require increasingly precise control over mechanical parameters such as torque in electric drives. Traditional methods of torque measurement, such as strain gauges with contact rings or indirect methods relying on phase current and voltage measurements, have significant limitations. Contact methods are prone to wear and inaccuracies due to mechanical friction, while indirect methods may introduce measurement errors in dynamic or non-stationary conditions. Given these limitations, the development of a contactless measurement system is critical for improving accuracy and reducing the maintenance demands on electric drives in various industrial sectors.

The purpose of this study is to design and simulate a system for contactless measurement of mechanical parameters, particularly torque, in electric drives. The developed system aims to be more accurate and reliable than existing solutions. The research also investigates the impact of the sensor on the performance of the entire electric drive system and provides recommendations for its practical implementation.

The main objective is to develop a reliable and accurate contactless sensor system for measuring mechanical parameters in electric drives, with a specific focus on torque control. This involves comparing various sensor designs, conducting simulations to identify the most suitable model, and validating the sensor's effectiveness through mathematical modeling and experimental setups.

The tasks include:

A comprehensive analysis of current methods for torque measurement in electric drives.

Selection and simulation of different sensor constructions to identify the optimal design.

Development of a mathematical model to simulate the sensor's impact on the electric drive system.

Design of test benches for further experimental validation.

Methods and Materials. An analysis of traditional methods for measuring the mechanical parameters of electric drives was conducted, including indirect methods, strain gauges with slip rings, and photoelastic transducers. However, all these methods have several significant drawbacks:

- Indirect methods: High measurement error due to changes in motor characteristics during operation.
- Strain gauges with slip rings: Contact wear and limitations on the maximum shaft speed.
- Photoelastic transducers: Installation complexity and low accuracy.

To overcome these limitations, a contactless magnetoelastic sensor was selected.

The developed ring-shaped magnetoelastic sensor, with a doubled number of measuring poles, offers several advantages:

- High noise immunity: The doubled number of measuring coils allows the device to effectively filter external electromagnetic interference.
- Compactness: The design enables integration into systems with limited space.
- Reliability: The absence of contact elements extends the device's service life.

Magnetic field simulation results showed that the sensor design ensures uniform field distribution around the entire shaft perimeter (Fig. 1).

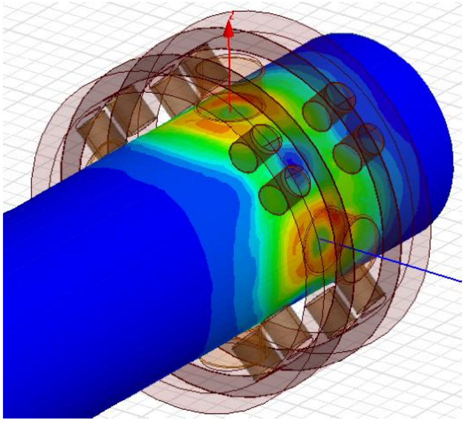

Fig. 1. Magnetic fields in the ring sensor with a doubled number of poles

An electric drive model was built in MATLAB Simulink, including two operating modes:

- Ideal mode (no sensor error considered).
- Real mode (accounting for the characteristics of the developed sensor).

A comparison of time-domain characteristics showed that peak torque deviations during sudden load changes did not exceed 2.3%, which is within the allowable error range (Fig. 2).

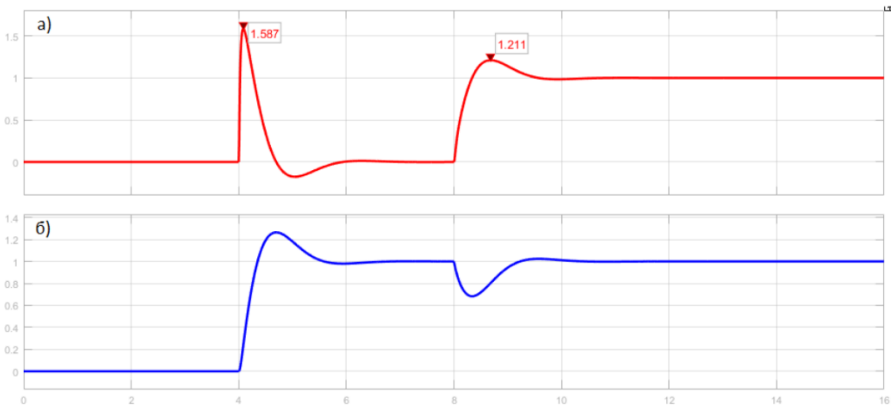

Fig. 2. Time-domain characteristics of torque and speed with the sensor

To validate the developed sensor, two types of test benches were created:

- Manual test bench: Allows basic measurements and sensor calibration.
- Automated test bench: Provides simulation of complex operating modes and recording of dynamic characteristics.

Tests on the benches demonstrated that the system operates reliably when measuring torque in the range of 500–700 Nm, ensuring high measurement accuracy and a fast response to load changes.

Special attention was given to the analysis of transient processes. The system effectively recorded torque changes with minimal delays, which is critical for applications in dynamic systems such as rolling mills and conveyor lines.

Figure 3 shows the transient processes during load changes, indicating that the torque stabilization time does not exceed 0.5 seconds.

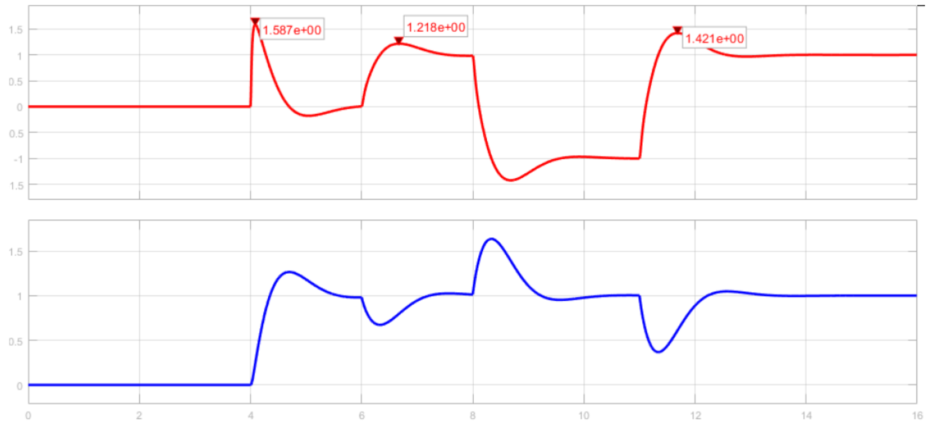

Fig. 3. Transient processes during load changes

Mathematical modeling demonstrated that incorporating the sensor into the control loop does not significantly affect the overall system dynamics. Regulation parameters remain stable, and the accuracy of maintaining the set torque improves.

Conclusions. The developed contactless system for measuring mechanical parameters in electric drives has demonstrated high accuracy, with a measurement error not exceeding 2.3%, and excellent sensitivity, ensuring precise torque control within the range of 500–700 N·m. The optimal sensor design was identified as a ring-shaped model with double poles, offering enhanced accuracy, reliability, and high resistance to noise.

Modeling and testing confirmed that the proposed system can be integrated into a wide range of industrial applications, including metallurgical plants, automated assembly lines, and transportation systems, without compromising the performance of electric drives. Due to its fast response time and resistance to external interference, the system is well-suited for dynamic processes that require precise parameter control.

Future work will focus on experimental validation of the sensor using the designed test benches, as well as exploring its potential applications in various industrial processes to enhance their efficiency and reliability.

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