# Modelling and diagnostics of rolling bearings used in permanent magnet synchronous motors

**Permanent Magnet Synchronous Motors** (PMSMs) are currently one of the most commonly used electric motors due to their high efficiency, dynamics, reliability, and compact size. Unfortunately, like any mechanical device, they can be damaged, and such damage can cause the entire industrial process to come to a halt, resulting in significant losses. Bearing failures in electric motors are one of the most common defects encountered during the exploitation of these machines. Bearings, which ensure the stable operation of the motor, enable the transfer of mechanical force generated in the motor to the working machine, allowing the proper functioning of the drive components. Defects in these elements can lead to various problems, such as increased noise, vibrations, decreased performance, and even serious motor failure. Evaluation of these phenomena is possible through analysis of diagnostic signals as well as simulation models based on a complex mathematical description.

Simulation studies are currently a popular and effective tool for analyzing complex problems in science and technology. The main benefit of their application is the high accuracy of the obtained results and the ability to dynamically change the physical parameters of a given model or operating conditions without the need to reconstruct the model of the analyzed phenomenon or object. Examples of practical applications of mathematical modeling include problems related to the design of electric machines, electromagnetic analysis, as well as projects involving structural analysis in construction or mechanics. Models developed based on the finite element method (FEM) can also provide information about characteristic features that can be used in damage analysis studies. By comparing the results of modeling and analysis with experimental data, a relationship between the system responses and the model parameters can be established, allowing for an understanding of the failure mechanisms. Therefore, the development of a reliable mathematical model of a bearing is crucial for accurately analyzing various types of damage and investigating the causes of their occurrence. Performing calculations for such precise simulation models requires significant computational resources, often exceeding the capabilities of standard personal computers. On the other hand, simple analytical models that only approximate the solutions of physical systems can be prone to errors. Hence, the practical application of diagnostic information may lead to prolonged detection time of damages or hinder the detection, which can result in interruptions in the operation of electric machines.

**The aim of the research** project is to develop, verify (through simulation and experimentation), analyze the operation, and improve the models of rolling bearings that will serve as a basis for diagnostic methods of damage detection in PMSMs. Within this project, the development of physical models of selected damages (inner race, outer race, rolling element, and cage) is envisioned, as well as computer models that incorporate the simulation of damages using analytical modeling and 2D/3D modeling based on the finite element method. The perspective of using FEM models for diagnosing damage in rolling bearings brings numerous benefits, including the creation of models that allow for early identification of rolling bearing issues (gradual damage progression), which can help in planning downtime and eliminating costly repairs. Additionally, advanced models will assist in preventing future failures by enabling real-time monitoring of the performance of rolling bearings in the motor.

**The scope of the research** work includes analyzing the drive system and testing the feasibility of damage detection based on signals derived from the control structure. For this purpose, numerical models will be employed in a co-simulation approach (parallel operation of the model of motor with a damaged bearing and the control system model). The obtained results will be compared with the results obtained from physical models. The next step is to develop diagnostic systems using solely the information obtained from simulation models. Such an approach enables the provision of precise information regarding damage symptoms to the diagnostic system, and it allows for the resignation of intentional machine damaging in order to develop the mentioned diagnostic symptoms. The use of FEM models for diagnosing damage in rolling bearings in a motor can bring numerous benefits. It can facilitate the development of fast and effective diagnostic methods, enabling the avoidance of destructive machine failures and production downtime.