**Ordinal Pattern Analysis for Early Bearing Fault Detection and Classification in Rotating Machinery**

**Abstract**

Bearings are critical components in rotating machines, but their demanding operating conditions with high loads and shocks often lead to various failures. These errors can result in significant downtime, costly maintenance, and even complete machine failure. Therefore, early and accurate detection and classification of bearing defects is critical to ensuring operational safety and minimizing maintenance costs. Traditional fault detection methods are mainly based on analyzing physical parameters and trends using vibration, thermal monitoring and current signature analysis techniques. Although these methods have been proven effective, they can be prone to interference and often require significant computational resources. Ordinal pattern analysis has emerged as a promising alternative, providing a robust and computationally efficient approach to analysing time series data. At its core, ordinal pattern analysis involves converting continuous time series data into a sequence of symbols that represent ordering relationships among data points within a specific time window. This approach effectively captures the fundamental dynamics of the signal in a way that is inherently robust to noise and distortion. By analysing these patterns, it becomes possible to identify subtle changes in system behaviour that may indicate the presence of an error. This study investigates the application of ordinal pattern analysis for early detection and classification of bearing defects, focusing on common defect types such as ball, outer ring, and inner ring defects. Using a publicly available dataset from the Case Western Reserve University Bearing Data Center, we demonstrate the effectiveness of ordinal patterns in distinguishing between healthy and failing bearing conditions.