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In-Process Monitoring of Gear Power Honing Using Vibration Signal Analysis and Machine Learning

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Objectives: In modern automotive transmission manufacturing, increasingly stringent Noise, Vibration, and Harshness (NVH) requirements [1] demand high-precision finishing of heat-treated gears, typically achieved through grinding or honing [2]. While Statistical Process Control (SPC) methods are commonly used to adjust process parameters based on component measurements, they fail to capture transient phenomena that can still compromise final product quality. Predicting the quality of finished components from real-time process data is an open research challenge [3], [4]. The aim of the present work is to propose a predictive AI-integrated method for gear quality assessment, leveraging vibration signal analysis.

Methodology: The method is based on continuous data acquisition via sensors installed on machine tools, integrated with SPC and involves time-frequency analysis of signals acquired via accelerometers. The proposed methodology extends the approach introduced in [5], where Principal Component Analysis (PCA) and a Support Vector Machine (SVM) model were used for bearing fault diagnosis through vibration spectrogram analysis. In this work, the principal components (eigen-spectrograms) are used to identify different machine operating conditions, providing a simplified representation of the initial dataset. These components were then used to train the SVM classification model to detect gear tooth defects.

Results: The model was trained and tested on an experimental dataset collected during machining, categorizing samples into three quality classes. The results demonstrate that the proposed method can accurately and efficiently distinguish between different quality levels, confirming previous findings on the reliability of vibration-based monitoring in grinding processes [3].

Conclusions: Findings suggest that the proposed model is suitable for industrial implementation in in-process monitoring. Furthermore, experimental evidence indicates that the non-stationary phenomena identified through principal component analysis are responsible for surface waviness on gear flanks, which in turn leads to unacceptable vibrations during transmission operation [2]. These results align with existing studies on grinding process dynamics and expand on previous methodologies for data-driven condition monitoring [5].

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