International Conference on 2025
7th June 2025

Enhancing Tool Wear Detection in CNC Milling: A comparative Study of Attention Based Deep Learning Models

Akshit Jain
Department of Production and Industrial Engineering, Delhi Technological University, Delhi, India

Rajesh Kaushal
Department of Production and Industrial Engineering, Delhi Technological University, Delhi, India

Jatin
Department of Production and Industrial Engineering, Delhi Technological University, Delhi, India

M. S. Niranjan
Department of Production and Industrial Engineering, Delhi Technological University, Delhi, India

Abstract:

Tool wear detection is critical in Computer Numeric Control (CNC) milling to maintain machining precision, reduce material waste, and extend tool life. Traditional methods, including manual inspection and basic sensor-based approaches, are often inefficient and prone to error, underscoring the need for automated, real-time solutions. This study investigates the effectiveness of deep learning (DL) models incorporating attention mechanisms for tool wear classification. Four architectures—CNN with attention, LSTM with attention, Hybrid CNN-LSTM with attention, and Transformer encoder—are evaluated on a benchmark machining dataset. Among the models tested, the Hybrid CNN-LSTM with attention achieves the highest accuracy of 99.85%, effectively capturing both spatial and temporal dependencies in the data. The LSTM with attention model follows with 99.69% accuracy, excelling in modeling sequential patterns. CNN with attention also performs well with 99.15% accuracy. In contrast, the Transformer encoder achieves comparatively lower accuracy at 89.3%, suggesting a need for further optimization for this specific application. The results highlight the strong potential of attention-based DL models in enhancing tool wear detection in smart manufacturing environments. Specifically, the Hybrid CNN-LSTM with attention model demonstrates suitability for real-time monitoring and predictive maintenance. This research contributes to the development of robust, automated systems for tool condition monitoring and lays the groundwork for future improvements in intelligent manufacturing technologies.

Keywords:

CNC Milling, Deep Learning, Attention Mechanism, Tool Wear Detection.