Acoustic wear monitoring during the milling of tool steel for machining 4.0

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INTRODUCTION

To efficiently digitize and automate the machining industry, it is essential to obtain data that can be precisely correlated to machining process condition. As the cutting tool is central to any machining operation, tool condition monitoring is used for data generation, production control and optimization. The research work presented herewith utilizes acoustic emission (AE) signals as a sensing method to provide adequate information on the cutting condition during the end-milling operation of tool steel for tool state prediction.

METHODOLOGY

Due to the pressing need for process optimization and sustainability in manufacturing, the cybernation of shop floor manufacturing is important. Under industry 4.0, individual steps of the value chain are linked and intercommunicate.

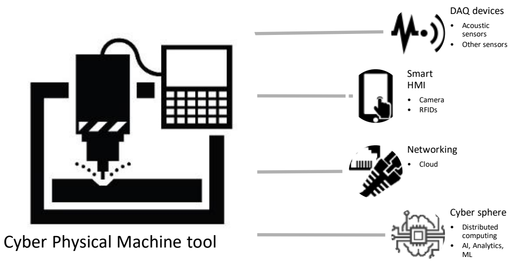


Fig.1 Cybernation of the manufacturing shop floor.

The part meant for production is designed for manufacturing using leading-edge analytics and established on data acquired from diverse sources such as sensors. Incorporated sensor-based tooling solutions permit the extraction of data from machining for optimization.

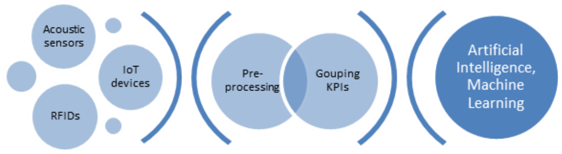


Fig.2 Phased process flow for smart manufacturing decision.

Acoustic emission (AE) is a powerful method in monitoring the cutting tool state [1]. Multisensory integration of correlated AE features provides more sensitivity and reliability in the prediction of tool wear states.

Class	Flank Wear (V_b)	Tool state
0	Vb < 0.1	New tool
1	0.1 < V_b < 0.2	Moderate
2	0.3 > V_b > 0.2	Worn tool

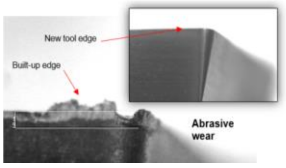


Fig.3 Tool wear classification and wear on tool edge.

A rectangular tool steel block of the workpiece was cut using a 25 mm end-mill indexable tool with TiAlN-PVD-coated carbide inserts. Repeated longitudinal cuts along its length using a combination of cutting parameters was used.

ACOUSTIC EMISSION SETUP

The modified cyber-physical machine tool in the shop floor consisted of a 5 axis CNC machine mounted with three Kistler AE sensors with a bandpass frequency ranging from 50 kHz to 1 MHz. The integrated acoustic sensors were affixed on the workpiece to supply a continuous elastic energy signal. Extensive processing of the AE waveforms by analogue signal preprocessing techniques was performed to mitigate the effects of its non-stationary and erratic transient nature. The output signal is then decomposed into features which generate correlated information vital to machining. These generated features act as inputs to decision-making models as well as a parameter for visual analyses of trends. AE signal extraction was utilized to generate time-domain, frequency-domain and time-frequency features. Additional features were also obtained using wavelet transform. Wavelet analysis works with the expansion of frequency band signals [2].

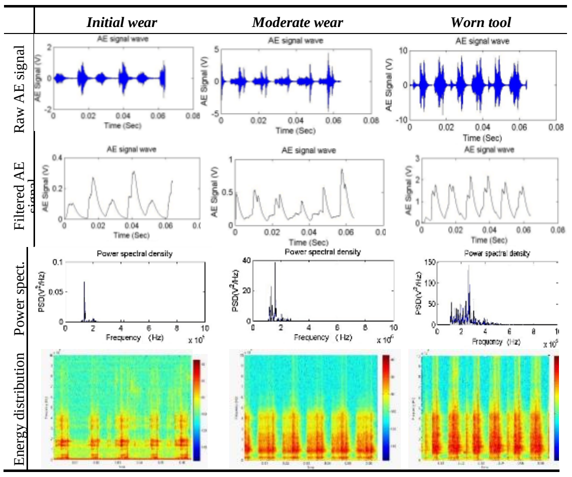


Fig.4 Processing stages of AE signal for different tool states.

RESULTS AND DISCUSSION

The Pearson correlation equation is utilized in feature selection to optimally reduce the feature set. The results identified a higher correlation between time-frequency AE features and tool wear as well as distinct time-domain features such as RMS and standard deviation

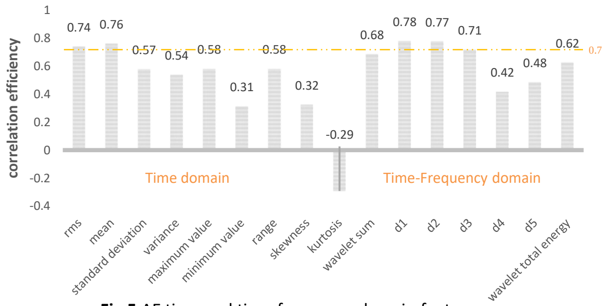
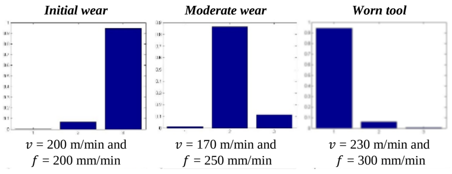


Fig.5 AE time and time-frequency domain features

Smart shop floors are powered by advanced software platforms able to incorporate and link the various virtual twin components of the manufacturing system in the cybersphere for process management. A cloud-based adaptation of this system permits the creation of a shared ecosphere of information for improved production. This cyber-physical data cloud performs the archiving, warehousing, searching and manipulation of sensing data to provide actionable information. As such, it permits not only the optimization of the machining process but also the autonomous scheduling of cutting tools and process intelligence which adheres to quality product requirements.

In this study, a feed-forward Backpropagation neural network (NN) framework was selected to perform the tool state prediction. Simulations to confirm the classification efficiency of the network was performed. Parametric tests of varying cutting conditions indicated with a binary output of 0 0 1 the tool's wear state.

Fig.6 Validation of the network with the various stages of wear.



CONCLUSION

This study highlights acoustic emission as a viable tool in the creation of a smart shop floor. A multi-sensing AE monitoring approach using various acquisition points are fusion and employed to ascertain the state of milling production.

REFERENCES

[1]. Pontuale, G., et al., *A statistical analysis of acoustic emission signals for tool condition monitoring (TCM).* Acoustics Research Letters Online, Published Online 14 November 2002(DOI 10.1121/1.1532370).

[2].Olufayo, O. and K. Abou-El-Hossein, *Tool life estimation based on acoustic emission monitoring in end-milling of H13 mould-steel.* International Journal of Advanced Manufacturing Technology, 2015. **81**(1-4): p. 39-51..