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An intelligent system for grinding wheel condition monitoring

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Abstract

The neural network and fuzzy logic are used to classify the condition of the grinding wheel cutting abilities for the external cylindrical grinding process. For each measuring signal a few statistical and spectral features are calculated and used as an input for data selection and classification procedures. First, a feed forward back propagation neural network was implemented to perform feature selection task from the multiple sensor system. Next, a neural network based fuzzy logic decision system for sensor integration in grinding wheel condition monitoring is discussed.

Keywords: Grinding wheel; Cylindrical grinding process; Fuzzy logic decision system

1. Introduction

The paper points at the design and implementation of a neural network and fuzzy logic based system combining the outputs of several sensors for grinding wheel condition monitoring. It can be assumed that in the case of grinding processes, the state of the process during a single grinding wheel life period is only a function of the changes in the wheel cutting ability. This is why the wheel condition monitoring plays a crucial role in any automated supervising system for a grinding process.

A successful grinding wheel condition monitoring depends to a great extent on reliable and robust sensors used for this purpose [1,2,4,5]. In the absence of human operators, the sensors must have the ability to recognize process abnormalities and initiate corrective action. There are various signals which correlate to the condition of the process and they are the subject of different sensing and processing techniques. Each of these signals is able to provide a feature related to the phenomenon of interest although at varying reliability. So to collect the maximum amount of information about the state of a process from a number of different sensors is the best solution. To introduce such an idea to practice an intelligent sensing system embodying strategies for sensor fusion should be implemented [1,3–5].

In this study, a monitoring system with multiple sensors is proposed and the performance of it is experimentally evaluated. This system includes the measurements of vibration, acoustic emission and grinding forces. They generate the useful signals for the grinding wheel wear monitoring but the best configuration of the signals and signal processing methods has to be selected. It is done by a feed forward back propagation neural network. After a tuning procedure of the network it was established that the number of informative features is much smaller than the initially used set of features. The same neural network can also be applied in the decision making procedure because, at the same time, it is able to model grinding wheel wear. Besides, a neural network based fuzzy logic decision system for sensor integration in grinding wheel condition monitoring is discussed.

In order to evaluate the proposed procedures, the data collected while grinding with a range of cutting parameters were used. The fresh, worn and partly worn grinding wheel was observed during the experiments. For each measuring signal a few statistical and spectral features are calculated and used as an input for data selection and classification procedures.

2. Experimental setup and data acquisition

The tests were conducted on the SWF 25 PONAR-JOTES modified cylindrical grinding machine [3]. The plunge grinding of 48 mm wide workpiece made of the 45 carbon steel hardened up to 24 HRC with the 38A80KVBE aluminum oxide wheel was used during the tests. The grinding parameters were as follows: cutting speed: 35 m/s, speed ratio: 120, grinding engagement: 2, 5 and 10 μm, grinding fluid: 3% water soluble emulsion with two volume rates of 12 and 7.5 l/min, dressing feed: 0.08 mm/rev, dressing engagement: 0.03 mm. The tests have been performed in working cycles which consisted of the 100–150 μm plunge grinding, the 2 s sparkout and the 20 μm rapid retraction.

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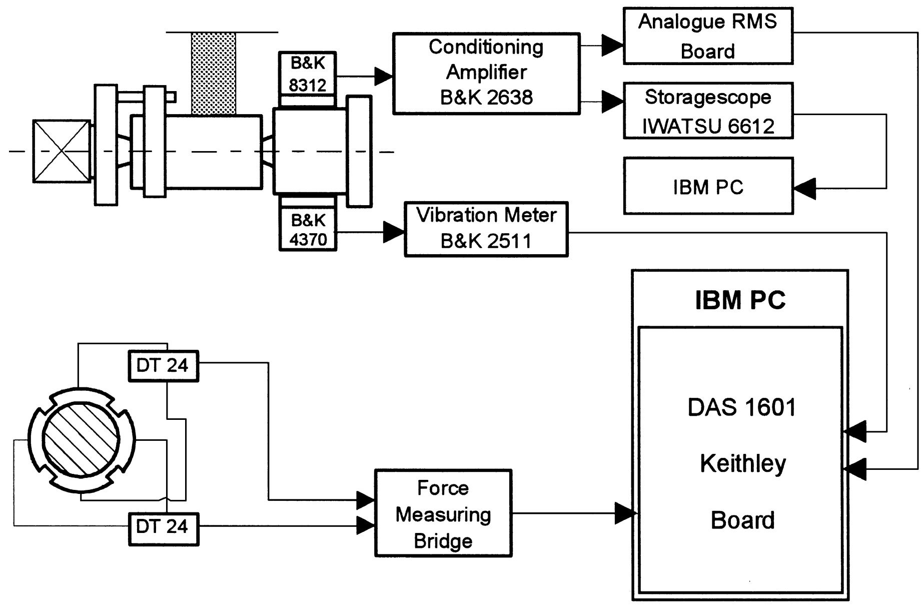

Fig. 1. Schematic of experimental setup.

A schematic of the experimental setup is shown in Fig. 1. The 8312 B&K piezoelectric AE transducer with a built-in 40 dB preamplifier has been attached to the center hub of the tailstock through a silicon film with the aid of mechanical clamp. The preamplified signal from the transducer is then amplified by the 2638 B&K wideband conditioning amplifier equipped with a range of filter facilities. The amplified and filtered signal is sent simultaneously to an analogue RMS board and to a digital storagescope. The analogue AE RMS signal has been processed through the DAS-1600 KEITHLEY data acquisition board and recorded by a PC. The raw AE signal has been sampled and stored in 8 KB segments of samples by the 6612 IWATSU storagescope and next recorded by a PC. The normal and tangential components of grinding forces and the mechanical vibration are measured as well. The difference in pressures inside the pockets of the spindle hydrostatic bearings is utilized for the measurement of grinding forces and the 4370 B&K piezoelectric transducer with the 2511 B&K vibration meter is used for the vibration measurement. All the measured signals are processed through the DAS-1600 KEITHLEY data acquisition board and recorded by a PC.

Using bandpass filtering, the AE signal was measured in the range of 50 kHz to 1 MHz, while the frequency range for the vibration was 0–5 kHz. The RMS value of the AE signal was evaluated by the analogue RMS circuit and next digitized with the sampling frequency of 10 kHz. The same sampling frequency was used for the vibration signal. Segments of the 2048 AE RMS and vibration samples were recorded by a PC every 1 s during the grinding cycles in a time share mode. The grinding forces were recorded continuously with the sampling frequency of 200 Hz.

The raw AE signal was collected using the storage oscilloscope which sampled the AE data at 5 MHz. A segment of the 8192 AE data samples was stored by the storagescope once during every grinding cycle. Next, this segment of data was sent to a PC and recorded. Such a procedure of the raw signal acquisition is necessary because of the extremely fast digitizing and the resulting huge amount of data which are able to fill a hard disk very soon.

To realize the aims of this research several signal processing techniques have been used. Representative segments of 2048 samples from the stationary part of the grinding cycles have been chosen for all the recorded signals. These segments of the vibration signal, the raw and AE RMS signals were transformed to the frequency domain using a power spectrum procedure. Next, the mean value, the variance, the standard deviation, the standard error, and the amplitude range of all the signal segments in time as well as frequency domain were calculated. For the forces signals, their levels and ratio between them have been calculated. Altogether, 33 features from the recorded signals have been extracted.

3. Neural network feature selection and modeling

The acquainted data have been preliminary analyzed to reduce the number of features used by the grinding wheel condition monitoring system. This analysis has allowed to select 14 features. No correlation with the wheel condition has been noticed for the discarded features or they have been correlated with the wheel condition in very similar but less readable way than other features (e.g. variation, standard deviation, standard error). Since the raw AE signal measurement would be very difficult for realization in a real-time system, a decision has also been made to discard all the features related to this signal.