Vibration Analysis
for
Predictive Maintenance

Bachelorarbeit

zur Erlangung des akademischen Grades „Bachelor of Science (B. Sc.)“
im Studiengang Wirtschaftsingenieur der Fakultät für Elektrotechnik und Informatik,
Fakultät für Maschinenbau und der Wirtschaftswissenschaftlichen Fakultät
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Hannover, den 01.03.2018

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1. Introduction

The ongoing evolution of the industry is facing a new era, introduced by the German government with the Industry 4.0 initiative. The initiative aims on a further digitalization of the production process and pursues the establishment of smart factories. Thus, intelligent machines are developed, which are interlinked with information and communication systems. As a consequence, this enables multiple new and innovative approaches for traditional industrial processes. Among these, Predictive Maintenance (PdM) is a concrete application for establishing a smart factory in the context of Industry 4.0. It is a sophisticated maintenance approach, which utilizes modern technologies to monitor the industrial equipment and to forecast upcoming failures. Therefore, PdM holds enormous potential for manufacturers in saving maintenance costs, as well as improving the quality of their product.

In the spring of 2017, the Hannover Messe hosted a special exhibition on PdM. What is more, the issue of PdM has been defined as a guiding theme of the trade fair. This demonstrates the currency and relevance of this new approach in maintenance for industrial companies. The relevance is further confirmed in the findings of a study, which was carried out by the consulting company Roland Berger in cooperation with VDMA, the association of German mechanical engineering industries. According to this study, 81% of the surveyed engineering firms are considering PdM. Moreover, 40% of those companies are already offering first solutions. The most anticipated benefits of PdM are cost reductions and performance gains. Thereby, the performance gains are estimated nearly four times as valuable as the cost reductions (Feldmann, 6f).

In order to perform PdM on industrial equipment, monitoring and analyzing specific machinery characteristics is mandatory, since the outcome provides the basis for failure prediction. Technological knowledge is essential to understand the significance of the measured machinery parameters. Furthermore, a succeeding PdM system depends on proper processing of the parameters to enhance their informative features. Of all the parameters, the machinery vibration seems to be a reasonable indicator on the condition of the equipment. Therefore, the importance arises to comprehend and analyze the characteristics of a machinery vibration signature. As a consequence, the application and examination of suitable vibration analysis techniques are crucial for the success of PdM.

7. Limitations

The subject matter of both, vibration analysis and Predictive Maintenance is extremely comprehensive. Therefore, the thesis can only focus on specific analytical aspects of vibration analysis for PdM. For this reason, the emphasis lays on the examination of the signal processing techniques of measured vibration data. However, there are further aspects to inspect.

Another essential part of PdM is the forecast of the remaining time until failure. This process relies on accurate information on the condition of the equipment, which is provided through vibration analysis. In order to attain an even more sophisticated PdM system, the approach of forecasting could therefore be more closely pursued. Concerning this matter, first deliberations suggest the connection between vibration analysis techniques and machine learning approaches. However, this is beyond the scope of the thesis.

Another limitation of the thesis arises, due to the nature of the provided bearing fault vibration dataset. Even though the database is very extensive, it only includes stationary vibration signals. As a consequence, the data is unsuitable for the experimental analysis of time-frequency signal processing techniques. For this reason, the signal processing techniques of Short Time Fourier Transform and Wavelet Transform are not put into practice in the thesis. As a consequence, these techniques can only be examined theoretically.

8. Conclusion

The innovative approach of Predictive Maintenance is in the ascendancy over the timeworn maintenance philosophies of Reactive Maintenance and Preventive Maintenance. Contrary to those, PdM is the only maintenance strategy, which reliably prevents machinery downtime, as it relies on monitoring and analyzing distinctive machinery parameters.

In this context, the analysis of emerging machinery vibration has proven to be particularly beneficial for performing PdM on rotary or reciprocal equipment. Especially the potential for instructive condition monitoring is demonstrated in the thesis. This potential of the vibration analysis is primarily justified by advanced possibilities for fault detection and fault diagnosis.

Typically, a vibration analysis is subdivided into data acquisition and signal processing. For the data acquisition, piezoelectric accelerometers are identified as the most suitable type of vibration transducer, since their measuring range covers the major frequency bands of machinery vibrations. After the data is acquired, the vibration signal is processed, in order to gain knowledge on the actual condition of the equipment. The processing techniques are either located in the time domain, frequency domain or time-frequency domain.

In the time domain, calculating the kurtosis value of the measured vibration signal is the most eligible method to indicate the machinery condition. Moreover, the envelope analysis and the cepstrum analysis are both convenient frequency domain vibration analysis techniques for detecting and even diagnosing a damage. Regarding the time-frequency domain, both the Short Time Fourier Transform and the Wavelet Transform provide a time-frequency distribution of the vibration energy, indicating transient faults. Overall, time domain analysis and frequency domain analysis are preferably applied on stationary vibration signals, while time-frequency analysis is necessary for nonstationary vibration. Hence, the conducted experiment focusses on the time domain analysis and the frequency domain analysis, since the provided bearing fault vibration signals are stationary. The experimental results provide substantial insight on the different processing techniques, which are applied on the measured vibration data.

The experimental application of the kurtosis value corroborates its ability to indicate a damage as well as the limitations in fault diagnosis. Thus, the kurtosis value proves its benefit as an auxiliary factor for PdM. Furthermore, the envelope analysis is able to diagnose specific faults in the experiment. Especially the characteristic demodulation of the analyzed vibration signature determines the success of envelope analysis. The application of CA on the bearing vibration signals also confirms the benefits of CA for diagnosing machinery faults. Envelope analysis and CA complement each other. Therefore, a combined application of the processing techniques on machinery vibration enhances the overall condition monitoring.

Conclusively, vibration analysis definitely benefits PdM, since the machinery vibration contains crucial information on the equipment, which is made accessible through vibration analysis. Consequently, vibration analysis is a resourceful strategy to further PdM.