Analyses of the most influential factors for vibration monitoring of planetary power transmissions in pellet mills by adaptive neuro-fuzzy technique

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ABSTRACT

Vibration-based structural health monitoring is widely recognized as an attractive strategy for early damage detection in civil structures. Vibration monitoring and prediction is important for any system since it can save many unpredictable behaviors of the system. If the vibration monitoring is properly managed, that can ensure economic and safe operations. Potentials for further improvement of vibration monitoring lie in the improvement of current control strategies. One of the options is the introduction of model predictive control. Multistep ahead predictive models of vibration are a starting point for creating a successful model predictive strategy. For the purpose of this article, predictive models of are created for vibration monitoring of planetary power transmissions in pellet mills. The models were developed using the novel method based on ANFIS (adaptive neuro fuzzy inference system). The aim of this study is to investigate the potential of ANFIS for selecting the most relevant variables for predictive models of vibration monitoring of pellet mills power transmission. The vibration data are collected by PIC (Programmable Interface Controller) microcontrollers. The goal of the predictive vibration monitoring of planetary power transmissions in pellet mills is to indicate deterioration in the vibration of the power transmissions before the actual failure occurs. The ANFIS process for variable selection was implemented in order to detect the predominant variables affecting the prediction of vibration monitoring. It was also used to select the minimal input subset of variables from the initial set of input variables – current and lagged variables (up to 11 steps) of vibration. The obtained results could be used for simplification of predictive methods so as to avoid multiple input variables. It was preferable to used models with less inputs because of overfitting between training and testing data. While the obtained results are promising, further work is required in order to get results that could be directly applied in practice.

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1. Introduction

Structural health monitoring is a discipline that aims to identify the health of a mechanical system through its lifecycle [1]. In the structural health monitoring field, vibration-based monitoring of structures is becoming more popular in recent years. This is owing to the fact that this type of systems will enable to keep track of the genuine health status of real structures under the disturbance of environmental and operational factors.

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Vibration monitoring, notably in the fields of civil, mechanical and aeronautical engineering, aims at detecting damages at an early stage, in general by using output-only vibration measurements under ambient excitation [2–4]. The detection of damages based on measured vibration data is a fundamental task for structural health monitoring to allow an automated damage diagnosis. If damages are detected early enough, they can be accommodated by maintaining the structures in appropriate operational states [5].

There are many different methods for vibration monitoring in different structural systems [6–10]. For example in paper [11] was proposed a model-based technique for detecting wear in a multistage planetary gearbox used by lifting cranes where proposed method establishes a vibration signal model which deals with cyclostationary and autoregressive models [12]. A vibration-based health monitoring system for a wind turbine under normal operational conditions was developed in [13] and the developed vibration-based health monitoring system of the wind turbine system is an efficient tool for understanding the structural dynamic behaviors that are important for designing, maintaining and managing the wind turbine system. In this context, paper [14] was focused on the responses of the dynamic properties of a wind turbine system to the complex environmental/operational factors, in order to explain the observed dynamic behaviors. A technique based on merging process and vibration data is proposed with the objective of improving the detection of mechanical faults in industrial systems working under variable operating conditions was proposed in [15] where results suggest that the combination of process and vibration data can effectively improve the detectability of mechanical faults in systems working under variable operating conditions. Vibration monitoring is one among many methods of technical diagnostics of a device by observing the level of a mechanical oscillation in a real time [9]. The mechanical oscillation is the manifestation of a device during its operation [15]. Certain parts become vibration exciters, others, depending on excitation, react specifically [5]. Therefore the vibration monitoring is one of the most important methods used in technical diagnostics for identifying a technical state [13]. With the use of vibration diagnostics an incipient failure can be detected, the place of an incipient failure can be located and the length of time during which a device is going to work before a failure occurs or a preventive action can be predicted [1,8,16,17].

In this study the main goal is to investigate vibration monitoring of planetary power transmissions in pellet mills is investigated. The goal of the predictive vibration monitoring of planetary power transmissions in pellet mills is to indicate deterioration in the vibration of the power transmissions before the actual failure occurs. In many cases, the defect does not cause an immediate interruption of the process. If this is the case, the defective part can be replaced or repaired during normal, scheduled maintenance periods, provided that the defect has been found in a sufficiently early stage. The most common causes of failure of rotary machines are faults in bearings, the stator and the rotor.

There are many methods for the predictive vibration monitoring of rotary machines. The analysis can be based on different measured quantities. These include, for example, temperature, current, magnetic flux density and vibration. However, vibration of pellet mills power transmission cannot be monitored using traditional vibration techniques, due to the complexity of the power transmission [18,19]. Therefore the basic idea is to create a measurement and data collection system based on soft computing method. The soft computing method could simplify the vibration monitoring process by reducing the number if inputs parameters.

When structuring vibration predictive models, it is crucial to include the most influential variables and discard the redundant and non-informative predictors. Additionally, it is important to identify and eliminate the potential multi-collinearity between the input variables. Correct variable selection will result in increased model predictability and interpretability.

In the literature, different approaches were used for selection of subset of most influential variables, but generally all the methods can be divided in two main categories [20]:

- filter methods and
- wrapper methods.

In filter methods the selection of model input variables is made prior to model training and tuning. On the other hand, in the wrapper approach the idea is to assess the predictive ability of various models with different combinations of input variables, using some error metrics, and to select the model producing the best results. While wrappers are more computationally demanding, especially for models having multiple tuning hyper-parameters, they can be regarded as a superior alternative as compared with filters [21].

In this article, we used the wrapper approach to select the most influential variables for vibration monitoring predictive models of pellet mills power transmission. The Adaptive Neuro-fuzzy Inference Technique (ANFIS) was applied to the available data sets to select the predominant model variables. Current (at moment t) and lagged (up to 10 steps) variables of the vibration were used for structuring the predictive models. An initial set of 11 potential variables was used for experiments.

2. Methodology

The goal of the predictive condition monitoring of planetary power transmissions in pellet mills is to indicate deterioration in the condition of the power transmissions before the actual failure occurs. In many cases, the defect does not