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Data Synchronization for Model-Based Process Monitoring

F. Klocke[a], B. Döbbeler[a], S. Goetz[a]*, D. Chandra[a]

[a]*WZL der RWTH Aachen University, Steinbachstraße 19, 52072 Aachen, Germany*

* Corresponding author. Tel.: +49 241 80 27566; fax: +49 241 80-22293 *E-mail address:* s.goetz@wzl.rwth-aachen.de

Abstract

Aerospace industry requires high quality parts that often have to fulfill highest safety standards. Hence, process monitoring plays an important role in keeping these goals. In the scope of Industrie 4.0 new approaches to enhance process monitoring technology have emerged, one of which being the merging of simulation with measurement data to increase the quality and reduce the necessity to teach the system first. Due to discrepancies between simulation data and the measured data, new ways of synchronizing the two data sources are required. This paper shows a way to merge simulated torque signals of a hobbing process with the measured effective power signals of the respective spindle motor.

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Keywords: Process monitoring; Industrie 4.0; Smart Manufacturing

* Corresponding author. Tel.: +49 241 80 27566; fax: +49 241 80-22293.
E-mail address: s.goetz@wzl.rwth-aachen.de

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1. Introduction

1.1. Challenges in Geared Turbo Fans

With the development in turbo engines towards higher efficiency and lower noise levels, the Geared Turbo Fan (GTF) has become a focus of research for many companies. In a GTF a gear separates the turbo fan from the low-pressure shaft. These gears are subject to very high loads and at the same time very strict safety requirements. [1] As tool wear is known to affect the Surface Integrity of gears, its monitoring gains considerable importance in the manufacturing of gears for GTF. [2]

Gear hobbing is one of the major gear manufacturing methods, as it has the highest efficiency with outstanding accuracy and quality. However, it has a highly complex kinematics and multi-flank chip formation. It is therefore difficult to predict the tool wear accurately. Especially when producing large gears, the decision if the current tool is capable of machining one more gear without reaching a critical wear status is often not possible. [3]

An online assessment of the hobbing tool can reduce this problem by giving the possibility to decide upon the tool status on a more objective basis and to prevent sudden tool failure during the machining.

1.2. State of the art

Monitoring of tool wear can be differentiated between online and offline monitoring, where the offline monitoring still prevails in industrial use due to a lack of reliable online tool wear monitoring systems [5]. However, recent research focused on developing online methods for tool wear monitoring, and some systems are already commercially available. These systems usually rely on indirect measurement, such as cutting forces, vibration, acoustic emission, spindle motor power and feed currents. [5] Especially for complex cutting operations, such as milling or hobbing, the combination of different sensor signals is often applied [6] [7]. Especially for real-time monitoring solutions, the synchronization of these merged signals is of high importance. [8] First approaches have been developed in the 1990ies, by that time mainly used for theoretical models. An example is the use of the Gaussian Mixture density by UEDA, which improves the likelihood of Artificial Neural Networks in signal processing and process monitoring [9]. Although this is not feasible for real-time data, other authors show how to use a wavelet transformation of both the motor spindle power as well as the power of the lathe drives to assess the machine tool condition. This is done by combining the different signal sources. [10] [11] Model-based process monitoring, however, requires the merging of signals from the same source. PRICKETT et al. show the coalescing of vibration signals from the X and Y axis in order to detect tool breakage irrespective of the cutting path [12]. Often, it is required to combine signals in different domains. YUQING et al. show an example of using wavelet transformation to combine vibration signals to create eight dimensionless parameters that are able to improve the accuracy of damage identification for NC machines [8]. However, the proposed model-based tool wear monitoring system for a hobbing process required the merging of power signals from the spindle motor as well as the torque signals of the hobbing tool as gained from the simulation, using SPARTApro®. It is assumed that the control path between the motor spindle and the cutting tool shows a PT_2-behavior, so that the above mentioned concepts are not feasible in the case at hand. Therefore, a new method of merging signals needs to be developed.

1.3. Research aim and approach

As stated above, model-based process monitoring as proposed in [13] requires the merging of signals from two different sources that are correlated by a PT_2 behavior. Furthermore, the synchronization of the two signal sources is very important due to the high dynamics of the process. The aim of this paper is hence to show a way to synchronize discrete data from two sources as well as a way to improve the simulation by applying the correct transfer behavior in such a way that it fits more strongly to the measurement data as provided by the effective power sensor. In order to achieve this goal, a cross-correlation approach is used for the synchronization and a MATLAB tool is shown that alters the simulated data.