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Model for Cutting Tools Usage Tracking by On-line Data Capturing and Analysis

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Abstract

A model to track the cutting usage has been developed. The application domain of the model is milling in the woodwork industry. The model involves the capturing of raw data from three different sources; the machine tool control, the Enterprise-Resource-Planning system and the tool management system. The data is analysed, the cutting distance is calculated and stored along with the data of the tool usage parameter settings. In order to predict the remaining tool life it is essential to know the actual tool usage. The usage is based on the tool life distance which is calculated by the movement data of the axis and various parameters of the numerical control system. Input for the calculation is the cutting path, the tool usage data and the end of life due to tool wear. With this information it is possible to forecast the estimated tool life by using machine learning algorithms. This forecast algorithm will predict more accurate results after each learning cycle. The developed model has been implemented as a smart service. The tool wear predictions are used for improvement of machine availability. Tool changes can be done in advance of large orders and machining can be operated with less supervision. Furthermore the shipping of tools between the manufacturers, the customer and the refurbishment can be optimised. Premature wear due to wrong settings or human error can be avoided. The system ensures a reliable exchange of information without paper work via the internet across company boarders for the whole life cycle of each tool.

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Keywords: Tool Wear; Cutting Tool, Machine Learning

1. Introduction and Motivation

Tool wear is not preventable in chip-forming machining. The chain of causation between cutting conditions and tool life has been empirically evaluated for certain process parameters. At these certain parameters the prediction of the remaining tool life is accurate. With different process parameters a calculated and estimated prediction is less accurate.

The correlation between additional process parameters could be determined with a high number of lab test runs. An alternative approach is to capture and analyse the tool operation data and the resulting wear.

New developments in manufacturing are machine integration and automated transmission of data [1]. The automated transmission of tool machine control data allows reasoning of the tool operation conditions. This data can be set into context of other production data such as process planning data and tool management. The combination of these different data sources create higher information out of the raw data.

Surveys have shown that tool costs are representing up to 8% of the total manufacturing costs. Due to personnel costs or machine down times because of wrong or missing tools, the number can increase up to 34% [2]. Therefore it is essential for the process planner to know the tool life of tool under certain cutting circumstances and plan tool replacement before tool wear results in bad quality parts or tool breakage.

Research of tool life has been conducted since the beginning of the 20th century. In 1907 Taylor [3] proved there is a correlation between cutting speed and tool life. This correlation and various other influencing factors on tool life have been studied extensively. All these studies were conducted in lab environments. The lab environment and conditions differ from the usage on the shop floor. The challenge is an application and adaption of these models in a real production environment

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where the individual wear of thousands of tools has to be predicted.

Therefore new approaches and models have to be developed to overcome these challenge.

2. State of the Art

State of the art in tool management, wear models and tool life prediction are considered.

2.1. State of the Art in Tool Management

Tool management systems are required to plan, control and monitor the tool material and information flow to increase the transparency in production systems and reduce tool costs.

Without tool management systems, machine operators need almost 20% of their working time to search tools and 15% of the manufacturing orders are late due to missing tools [4]. These systems can be divided into 5 main functions:

- tool planning
- tool management
- tool scheduling
- tool supply
- tool usage

The tool planning consist mainly of order-independent functions to plan the tool range for future processing tasks. The tool management works on tool procurement, tool inventory management and tool requirement planning. To provide the right tools at the right time in the correct number and quality for the planned processing, tool scheduling has to be planned.

Due to the fact some tools get reconditioned for their next usage, the tool flow can be represented as cycle. The physical tool cycle shows the supply up to the usage on the tool machines. These last two functions of Tool Management System are located on the shop floor [4].

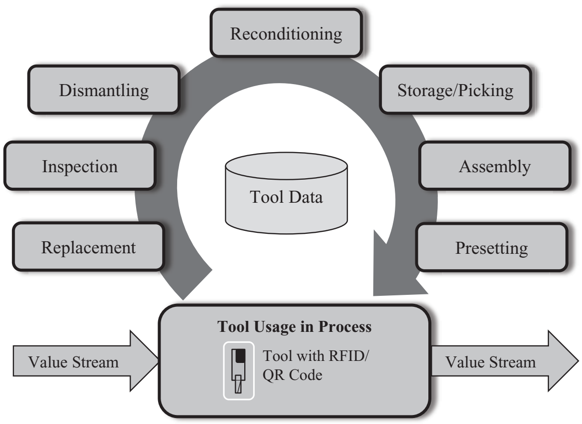


Fig. 1 Physical Tool Cycle

Figure 1 shows the physical tool cycle with all stations. The tool supply is responsible for the tool inspection, the tool dismantling, tool reconditioning, for the tool storage and commissioning, the tool assembly and presetting and finally the tool replacement. To realise an adequate tool flow, transport systems have to be installed. All actions lead to the main cycle station: the tool usage [5].

Identification systems should support the information flow through the different stations. Various research projects have evaluated and verified the usage of RFID tags or optical codes, such as QR Codes, on the tool holder or on the tool itself [6],[7],[8].

Tool Data Management systems support the Tool Management System by providing actual tool data for all five main functions through the tool life cycle. The information structures can be divided into:

Process data:

- geometrical data
- technological information

Administrative data:

- identification data
- organisational data

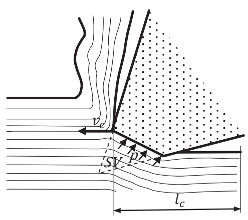
Condition and historical data which are partly linked to process and administrative data [9].

2.2. *Existing Tool Wear Models*

The application domain of this model is the woodwork industry. Therefore the considered models are for wood machining application.

To this date numerous experimental wear studies have been conducted [10],[11]. The generalisation of the conducted experiments was achieved by Fischer [12],[13]. His model explains the cause of the wear and also the wear progression.

By exceeding the specific compression strength or threshold pressure (See Fig 2a) cutting material gets removed.



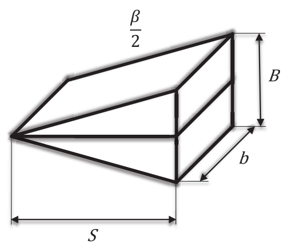


Fig. 2a Wear Model Fig.2b Cutting Edge Variables

The loss of cutting material and the therefore connected loss of volume is constant with constant cutting conditions.

2.3. *Tool Life Prediction*

Tool life testing can be performed with specific cutting parameters and a defined setup [14]. The tool life is measured with this process parameter setting. The tool life with process parameter variations within the process field can only be determined with numerous similar test runs. The cutting conditions are constantly different for milling with changes in the tool path direction. State of the art in the industry is the counting of the parts which can be manufactured before the cutting tool reaches the end of life criteria.

This practice is not useable with high part variations.

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