Available online at www.sciencedirect.com
ScienceDirect
Procedia Technology 26 (2016) 20 – 26
Procedia Technology

3rd International Conference on System-integrated Intelligence: New Challenges for Product and Production Engineering, SysInt 2016

Adaptive state-space model for ultra-precision feed axis

Arne Bloem[a,*], Christian Schenck[a], Bernd Kuhfuss[a]

[a]*bime Bremen Institute for Mechanical Engineering, MAPEX Center for Materials and Processing, University of Bremen, Badgasteiner Str. 1, Bremen 28359, Germany*

Abstract

One method to produce surfaces with optical properties is the ultra precision cutting. This method allows to create surfaces not only with a roughness of few nanometers but also with low form deviations. Beside the use of advanced cutting technologies with diamond tools the path of the cutting edge is controlled very precisely. The main measures used to attain this precision are the increase of the base accuracy of the machine tool, the protection against environmental influences especially the temperature, and the prevention of dynamic loads on the machine tool. However, the last point in particular is realized by slow and smooth motions of the machine axes, which result in very long processing times of multiple hours to days per work piece. One method to increase the velocities and the accelerations is to predict and compensate the resulting tool path error. This requires a precise model of the machine tool. The parameters of this model need to be identified accurately. Furthermore, the precision of the model can be increased if the parameters are not only identified once, but repeatedly. This enables to adapt the model to parameter changes, which occur due to external and internal influences like temperature shifts, mass change and wear. For this purpose a model is built, which consists of two state-space submodels that represent the motion band and residual band features separately. The parameters of this model are adjusted by the prediction error method. The reaction time between the change of a parameter in the physical world and the adjustment of the related parameter value in the model must be short enough, so that the dynamic tool path error is kept inside the tolerance. This time period limits the bandwidth of available measurements. With this limitation of the dataset, the parameter identification becomes even more difficult. Still, to achieve accurate estimations of the parameters the search space for the identification is reduced by limiting the single parameters of the model. In this work this method is applied to an experimental setup. The precision of this approach is analyzed under varied conditions.

Peer-review under responsibility of the organizing committee of SysInt 2016

Keywords: ultra precision machining; adaptive control; state-space model; prediction error method

1. Introduction

Parts with surface roughness values of few nanometers as well as form deviation values of few micrometers can be manufactured by ultra precision milling [1]. In these processes a main factor for the resulting roughness is the kinematic roughness, which is basically the imprint of the path and outer diameter of the cutting tool on the processed

* Corresponding author. Tel.: +49-421-218-64805.
E-mail address: bloem@bime.de

Peer-review under responsibility of the organizing committee of SysInt 2016
doi:10.1016/j.protcy.2016.08.004

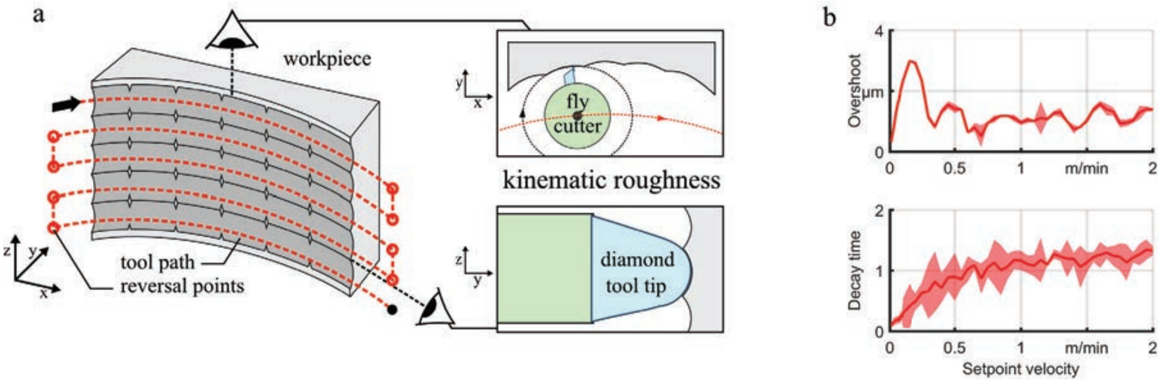

Fig. 1. Sources of long processing times. (a) Raster milling tool path and kinematic roughness (not to scale). (b) Dynamic deviation of an ultra precision feed axis.

surface. In, for example, a raster milling process the kinematic roughness is kept low by placing the single cuts of the cutter close to each other [2]. This requires very long tool paths with many reversal points, e.g. see Fig. 1b.

This is especially problematic, since loads on the machines feed axes need to be kept low to reduce vibrations and position deviations. For instance, even low velocities or accelerations induce a relatively large position overshoot in positioning tests, see Fig. 1a. Furthermore, this position deviations need a long time to decay, see Fig. 1a. The resulting low applicable velocities and long decay times as well as the long tool paths result in very long processing times.

To decrease the production times model based control methods are necessary to compensate the deviations and vibrations even at higher velocities. However, since the compensation results depend on the representation accuracy of the model, a model is necessary that meets the requirements and especially the resolution of ultra precision manufacturing.

The representation accuracy of a model is mainly determined by its structure and its parameters. The structure affects the accuracy by how precise it is able to reproduce the behavior of the kind of physical entity. The parameters affect the accuracy by how precisely they are adjusted. Typically, in the practical realization of a model both the model structure and the parameters values identification exhibit errors. The structure because it is based on isolated assumptions, which usually contain simplifications and are incomplete. The parameters because they can not be estimated with infinite accuracy. Further, the real parameters may change over time, which is caused by external influences that are not part of the model structure.

Nomenclature

n	degree of the state space model
x	state vector
t	time
u	model input
A	state matrix
B	input matrix
C	output matrix
e	deviation of the model
θ_{est}	estimated parameters
y_{mea}	measured output of the feed axis
w_{est}	window size of the estimation
p_{est}	parameter change limit