

Local characterisation of variances for the planning and configuration of process chains in micro manufacturing



Daniel Rippel^{*,1}, Michael Lütjen, Michael Freitag

BIBA – Bremer Institut für Produktion und Logistik GmbH at the University of Bremen, Hochschulring 20, 28359 Bremen, Germany

ARTICLE INFO

Article history:

Received 4 May 2016

Received in revised form 9 February 2017

Accepted 12 February 2017

Keywords:

Micro manufacturing
Process chain planning
Process configuration
Cause-effect relations
Variance characterisation

ABSTRACT

During the last decades, a continuous trend towards miniaturisation leads to an increasing demand of metallic micromechanical components. To achieve an economic production on an industrial scale, the planning and configuration of process chains has become a key success factor. Thereby, the occurrence of so-called size-effects renders the planning and particularly the configuration of process chains complicated. While process planners have to ensure very small tolerances, these size-effects lead to comparably strong variances within the behaviour of processes. To cope with these, this article proposes an extension to the μ -ProPIAn methodology. While μ -ProPIAn, in its current state, provides tools to characterise and utilise interdependencies between production relevant parameters, it lacks the capabilities to quantify and use variances for the prediction of process results. In this article, we propose an extension to this methodology, enabling a local estimation of variance of relevant process parameters using sample data. As a result, the planning quality can be increased as additional goals and methods for optimisation become available.

© 2017 The Society of Manufacturing Engineers. Published by Elsevier Ltd. All rights reserved.

1. Introduction

During the last years the demand for metallic micro components has increased continuously. While the components themselves become smaller, the complexity and level of functionality constantly increases [1,2,3]. Besides the development of more complex applications for micro components, the ongoing inclusion of micro components in applications within the growth areas of medical- and consumer-electronics constitute major drivers behind this development [3]. Aside from the so called Micro-Electro-Mechanical-Systems (MEMS), which are generally produced using methods from the semi-conductor industry, the demand for metallic micromechanical components increases similarly. These components are usually used for electrical or mechanical connections of and between MEMS as connectors, casings, contacts etc. Usually, these micromechanical components cannot be manufactured using semi-conductor based processes, so that processes from the areas of micro forming, micro injection, micro milling etc. are applied [2,4]. In particular, processes from the area of cold forming show great potential for the realisation of an economic, industrial production of metallic micromechanical com-

ponents. Generally, these processes can provide high throughput at comparably low energy and waste costs [5].

An industrial production of such components is usually characterised by very high throughput, sometimes up to several hundred parts per minute [6], whereby very small tolerances have to be achieved. These small tolerances originate from the small dimensions of the micro components. These components are by definition smaller than one millimetre in at least two geometrical dimensions [7]. In addition, so called size-effects lead to increasing uncertainties, variations and unexpected process behaviours when processes, originating from the macro domain, are scaled down to the micro level [8]. Moreover, micro manufacturing constitutes an active and relatively young field of interest for researchers and industrials, so that new or enhanced processes and machines are being developed continuously.

As a result, the planning and configuration of process chains constitutes a major factor of success for an industrial production of metallic micromechanical components [9]. Due to the occurring size-effects, companies require a very precise planning not only of the single processes configurations, but also along the complete process chain. Thereby, they have to regard the interrelationships between parameters of processes, materials, tools and devices. Small variations in single parameters can have significant influences along the process chain and can finally impede the compliance with the respective tolerances [10].

* Corresponding author.

E-mail address: rip@biba.uni-bremen.de (D. Rippel).

¹ www.ips.biba.uni-bremen.de.

One major challenge for the design and configuration of process chains in micro manufacturing is characterised by the small tolerances, which are contrasted by comparably high variances during processing as well as within material characteristics. Thereby, the variances are introduced and amplified by the occurrence of size-effects further detailed in Section 1.1. As a result, these variances constitute a major influential factor on the quality of planned process chains and thus, on the efficiency of the overall production system.

This article extends the Micro – Processes Planning and Analysis (μ -ProPIAn) methodology, which was originally designed to provide the necessary tools and procedures for an accurate design and configuration of process chains within the micro domain (see e.g. [10,11]). The methodology itself provides a set of methods to graphically model, plan and evaluate process chains across different levels of granularity. Nevertheless at this point, it does not provide the necessary methods to cope with the strong influence of variations induced by size-effects. This article aims to propose a method to characterise these variances based on experimental or production related data and to provide these information during the design and configuration of new process chains. Consequently, process designers will be enabled to estimate and optimise the expected variances, in order to achieve more stable process chains.

The remainder of this section provides a short description of occurring size-effects, followed by an overview of the state of the art in process planning within the micro domain. The next section gives a short introduction to the μ -ProPIAn methodology and its components. The third section describes the newly proposed extension of the μ -ProPIAn methodology, which adds the ability to characterise variances during the modelling stage. Section four provides an evaluation of the proposed approach in terms of its characteristics and estimation results. The article closes with a discussion on how this additional information can be used to enhance the planning accuracy.

1.1. Size-Effects in micro cold forming

Although cold forming processes are well established in macro manufacturing for mass production, they cannot simply be scaled down for micro manufacturing. The downscaling of those processes, and thus of the work pieces, tools and devices, is only possible up to a certain degree. With a decreasing scale, so called size-effects begin to emerge, requiring adaptations to the processes.

Vollertsen defines size-effects as “deviations from intensive or proportional extrapolated extensive values of a process, which occur when scaling the geometrical dimensions” [8]. In this context, he on the one hand defines intensive values as parameters, which are not expected to change due to a change of an object’s mass (e.g. its temperature or its density). On the other hand, extensive values are expected to vary with a different mass (e.g. the object’s inertia force or its heat content). In general, size-effects occur due to the inability to scale all relevant process parameters equally [8]. For example, the downscaling of a metal sheet’s thickness can result in a varying density due to local defects, although the density is considered an intensive variable. In macro manufacturing these variations can usually be ignored, while they can have drastic influences in micro manufacturing. Moreover, technical limitations can further facilitate the occurrence of size-effects. For example, the downscaling of mechanical grippers is limited by technical factors. For very small work pieces, Van-der-Waals forces between the gripper and the work piece will eventually overcome the gravitational force at a certain point of miniaturisation. As a result, the gripper will not be able to release the work piece without aid. Basically, Vollertsen defines three distinct categories of size-effects (Fig. 1) [8]:

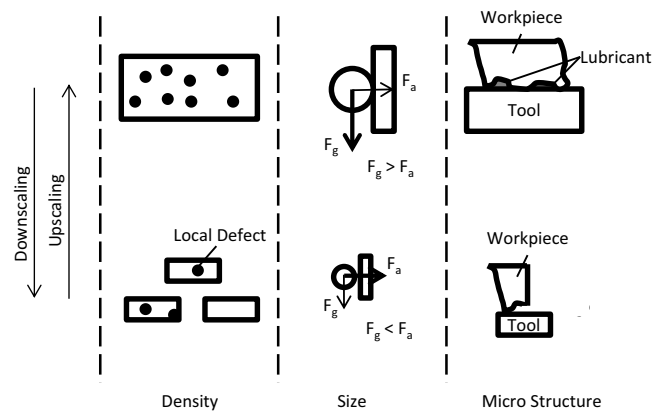


Fig. 1. Categories of Size-Effects [8].

- Density size-effects occur, when the density of a material is held constant while scaling down its geometrical dimensions. For instance, local defects become more serious with a continuing miniaturisation. Thereby, the distribution of local defects within a material can lead to more delimited sets of good and bad parts.
- Shape size-effects occur due to the increasing ratio of an object’s total surface area, compared to its volume. An example of this category is provided by the described imbalance of the adhesive force in relation to the gravitational force.
- Micro structure size-effects occur because micro structural features (e.g. the grain size or the surface roughness) cannot be scaled down the same way as the geometrical size of an object.

The occurrence of size-effects requires precise planning and configuration of all relevant technical parameters throughout a process chain. As a result of the size-effects and as new processes and technologies for micro manufacturing emerge quickly, interrelations between those parameters cannot be described comprehensively or are entirely unknown in several cases. In particular, the occurrence of density size-effects induces comparably strong variations e.g. to material properties. Together with the small tolerances in micro manufacturing, these variations further complicate the planning process, as they can strongly influence a products quality. Consequently, the process planning and configuration should not only rely on mean or expected values, but has to regard the variations induced by size-effects or the general process behaviour.

1.2. Process planning and configuration in micro manufacturing

Within the literature, there are only very few approaches which allow a joint planning of process chains as well as the configuration of the involved processes. During the last years, different articles focused on the configuration of specific processes (compare e.g. [12]). Thereby, the configuration relies on detailed studies of the corresponding processes and is usually supported by very detailed physical models in form of finite element simulations (e.g. [9,13]). Another approach found in the literature focusses on the use of sample data (historical or experimental) as templates for the configuration of processes (e.g. [14]). Although these approaches enable a very precise configuration of a single process, the interrelations between different processes cannot be considered easily. Moreover, the construction of finite element simulations as well as the direct application of historical information requires a very precise understanding of the processes, which in many cases is unavailable due to size-effects or the novelty of processes.

Usually, classic methods like, event-driven process chains, UML or simple flow charts are used in the context of process chain plan-

Download English Version:

<https://daneshyari.com/en/article/5469527>

Download Persian Version:

<https://daneshyari.com/article/5469527>

[Daneshyari.com](https://daneshyari.com)