Data Mining Approach for Identifying Optimal Process Parameters in Micro-Manufacturing

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Abstract

Micro-manufacturing processes are often characterized by unknown correlations between process parameters and quality characteristics. Due to the large amount of process data a systematic approach is needed. This paper describes an approach to use data mining methods on production data from micro manufacturing processes. A micro powder injection molding process is used as an example to validate the approach and the results of an initial analysis are presented.

1 Introduction

The demand for miniaturized micro-components with integrated functionality is rising especially in the medical and automotive industries. This has resulted in increased demands on the quality of micro-components. However, during the development of micro-manufacturing processes, the processes can often be unstable. This can be caused by unknown correlations between process parameters and the desired quality characteristics [1]. This paper presents an approach for identifying the optimal process parameters of micro-manufacturing processes through the application of data mining methods. To demonstrate the method, it will be applied to data from a combined micro powder injection molding (µ-PIM) and sinter joining process at the wbk Institute of Production Science of the Karlsruhe Institute of Technology (KIT).

2 Data Mining in Micro Manufacturing

Design of experiments (DOE) is a common approach for experimentally determining the influence and possible interactions of certain process parameters on the process result. To reduce the number of necessary trials, DOE applies what is known as a factorial experiment. In this approach the process parameters are simultaneously and systematically varied in predefined intervals. However, this is not practical for

experiments in which the desired parameter variations are in micrometer dimensions due to the high effort required to systematically vary the process parameters. Furthermore micro-manufacturing is often characterized by instable processes with process parameters, which cannot always be suitably controlled during process development. An alternative approach is to use data collected from experiments with randomly distributed parameters. Data mining methods capable of recognizing patterns and extracting information from such data sets are predestined for this application. Furthermore, data mining methods can even be applied to existing manufacturing data, thereby providing an opportunity to improve processes without performing costly and time-consuming experiments [2].

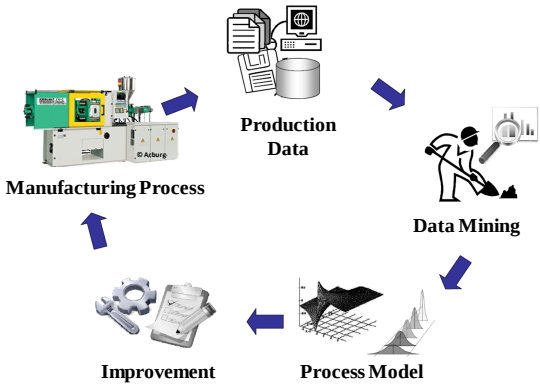

Figure 1: Data mining process for manufacturing data

Fig. 1 shows the principal process for using data mining methods for manufacturing data. In the production process a wide range of different data is collected. Via data mining a process model can be established that describes the influence of the process parameters on quality characteristics. With this knowledge the significant process parameters can be optimized in such a way that the required quality can be achieved.

3 Micro Powder Injection Molding

Sinter joining is an innovative joining method for micro engineering [1]. The process refers to the assembly of separate powder injection molded components in their green state (i.e. before sintering), and the use of thermally induced effects during sintering to join the components. So far, the assembly has required several down-stream

mounting processes. The process of sinter-joining allows for component assemblies to be molded as separate low-complexity parts which are then joined into complex assemblies. Fig. 2 illustrates the principle of sinter joining by the example of a shaft-to-collar connection, which has already been successfully implemented at wbk Institute of Production Science. Actual research activities attend producing assemblies with higher complexity, such as hollow assemblies with undercuts, cavities, micro structures and moveable components.

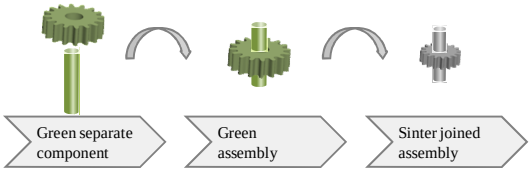

Figure 2: principle of sinter joining by the example of a shaft-to-collar connection

The result of the sinter joining connection depends on a variety of process parameters, whose impacts have not yet been analysed in detail. Figure 3 shows potentially influencing factors along the process flow.

process step	 Injection Moulding	 Assembling	 Debinding & Sintering
Influencing factors	▪ material (feedstock) properties ▪ pressure profile ▪ temperature profile ▪ injection rate ▪ tool properties ▪ ambience conditions ▪ etc.	▪ handling forces ▪ assembling forces ▪ positioning accuracy ▪ part parameter ▪ etc.	▪ temperature profile ▪ gas profile ▪ duration of thermal process ▪ part parameter ▪ etc.

Figure 3: Sinter joining: process steps and influencing factors

4 Application of Data Mining Method on µ-PIM Process

In this experimental set-up, trials were performed to determine the effect of process parameters on the amount of internal pressure, which can be withstood by the assembled probes before bursting. Through the application of multivariate regression, a better understanding of the process was obtained. Figure 4 shows the relationship between the difference of the taper angles, the surface roughness and the obtained internal pressure.

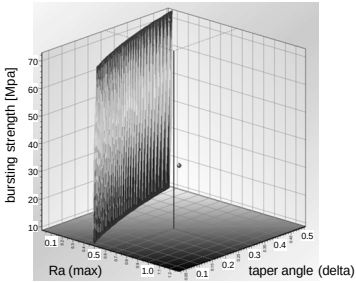

Figure 4: calculated multivariate model of bursting strength

During the trials a disturbance caused the temperature in the staging area of the oven to vary. The temperature variation was determined to have statistically significant impact on the bursting strength of the probes. This example illustrates how data mining methods can be used to identify the influence of important process parameters even if they are not systematically and deliberately varied.

5 Summary and Outlook

The presented approach via data mining enables the identification of optimal process parameters for micro-manufacturing processes, in which deliberate variation of parameters is limited, thus eliminating the need to perform extensive experiments. The approach can not only be applied to processes, which are still in development, but also to production data from existing processes.

Acknowledgments

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