Integrated Micro Process Chains

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Abstract. High quality mechanical manufacturing of small components and subassemblies having geometric features in the micrometer range requires controlled and coordinated processes. Considering full automation of the production process as essential, not only manufacturing processes have to be optimized but also handling and quality assurance operations take an integral part of the production process. We outline requirements for handling and test operations in micro production and introduce a concept of an integrated micro process chain which meets the conditions and challenges in micro production process planning.

Keywords: micro manufacturing, production planning, artificial neural network, quality, handling

1 Introduction

Micro systems technology is one of the most important cross-sectional technologies and the trend of miniaturization will outlast the next decades [1]. In comparison to chip manufacturing, micro production with mechanical manufacturing methods is not yet widely advanced. Manufacturing technologies and the development of concepts supporting the industrial production of micro components is still an active field of research. The Collaborative Research Center (CRC) 747, an interdisciplinary research project involving eight institutes of the University of Bremen, is focused on micro cold forming. Processes are developed for mechanically manufactured components and subassemblies, made from parts smaller than 1 mm in at least two dimensions, but having geometric features at the micro scale.

In the present state of research, the percentage of manually effected operations is still very high. This concerns handling operations like positioning and transport of micro parts. In order to reach production rates of up to 200 parts per minute with a throughput of several hundred to hundred-thousand parts per series, micro processes have to be automated. Quality control and handling operations are an integral part of the production process and have to be adapted to the speed and tolerances of the manufacturing process. In a field where accuracy deviations of one micrometer can have disastrous effects, an automated process chain is not realizable without controlled and monitored processes. Besides the improvement of the manufacturing methods themselves, which is not topic of this paper, the development of supporting systems like handling and measurement technologies as well as concepts for process planning and process-oriented quality assurance are the challenges faced by research in micro production.

2 Characteristics of Micro Production

Downscaling macro processes to micro scale works out up to a certain extent. The occurring *size effects* [2] describe several phenomena, which have physical and structural sources. In addition to the technical effects, production and logistics related effects like the possible use of smaller machines lead to new possibilities and challenges in production planning. Due to the lack of stable processes and standardized interfaces as well as suitable handling and measurement methods in the micro scale, production process planning is joined with and has to be integrated in the product development process. The following characteristics describe relevant conditions in micro production processes:

- High production volumes and high accuracy require an automated process chain,
- the parameters influencing the quality are increasing,
- due to highly sensitive processes, the quality of the product can vary widely,
- measurement and handling techniques have to be adapted for micro parts and processes (e.g. high production rates, high accuracies, suitable for clean-room)

In the following chapters the specific conditions of the areas, handling and material flow as well as quality control, are discussed in more detail.

3 Handling and Material Flow in Micro Production

Due to the increased surface-to-volume ratio of micro parts, their gravitational force is lower than the adhesion forces. Therefore, controlled picking and highly accurate placing of micro parts is a great challenge. Several research groups have developed handling devices; examples are given for micro-grippers [4], assembly [5], and transportation [6]. As described in [7], micro grippers should be designed in a way to fulfill the following requirements.

- Cost efficient and fast set up
- Small size, compact design and low weight
- Suitable for clean-rooms
- Ability to measure and control grip force in order to avoid destruction of fragile parts
- Integration of sensors to control and enable precise picking and placing
- Flexibility regarding object size and geometry able to be gripped
- Standardized interface (mechanical, electrical)

As the micro parts are very sensitive to electrical and mechanical forces as well as contamination, contactless handling is advantageous. Furthermore, the alignment and orientation of micro parts is difficult once they are disarranged. Therefore, the aim is to keep the parts in a defined orientation throughout the production process. This means, that the subassemblies and components are either produced in a larger composite and separated as late as possible or are placed in a component carrier right after processing. In both ways, they can be handled like macro parts with standard conveyer machinery.

4 Quality Management in Micro Production

Quality management systems are generally based on the ISO 9000 [3]. In this paper, we concentrate on micro part control and the consequences for quality assurance. Quality assurance describes processes and procedures as well as measurement technologies in order to attain quality objectives. The material and information flow define the requirements for quality assurance. Figure 1 gives an overview of a process-based quality management system.

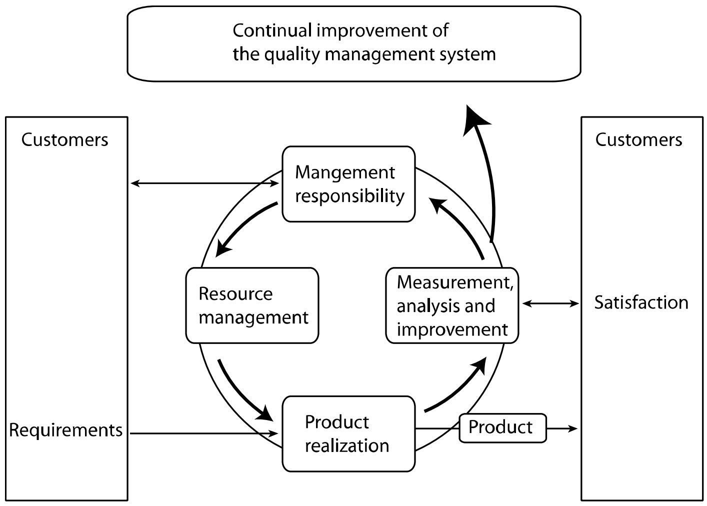

Fig. 1. Process-based quality management system [3]

It is a challenge to develop a quality management system for micro production as processes cannot be controlled sufficiently. Referring to ISO 9000 the development of a quality management system consists of the following steps [3]:

1. Determining the needs and expectations of customers and other interested parties
2. Establishing the quality policy and quality objectives of the organization
3. Determining the processes and responsibilities necessary to attain the quality objectives
4. Establishing methods to measure the effectiveness and efficiency of each process
5. Applying these measures to determine the effectiveness and efficiency of each process
6. Determining means of preventing nonconformities and eliminating their causes

7. Establishing and applying a process for continual improvement of the quality management system

As it is impossible to handle and test micro parts manually, it is necessary to focus research activities on measurement and test engineering: Features for a quality test have to be defined, an appropriate measuring technique has to be chosen and an automated method for quality tests has to be developed.

The objectives of a quality test consist of comparing features from a produced part with the optimal values taken from a design drawing or reference values. Features might be geometrical properties, surface properties or material properties. Afterwards a statement is made from the results of the quality test. This could be a decision about a violation of any chosen property or a detailed description of the violated quality property. Within the CRC quality properties are restricted to geometrical and surface properties and each violated feature is described in detail such that an analysis of the process is possible.

Possible measuring techniques to make a statement about the geometrical and surface properties of a micro part have to provide three-dimensional data. Jiang [8] has divided such measuring techniques in active and passive techniques. Passive techniques use light sources of the environment and active techniques submit light into the scene. A detailed overview of measuring techniques is given in [8]. Existing measuring techniques are appropriate to measure single micro parts but are not suitable to acquire 3D-information of many parts per minute. Therefore, a new system is developed within the CRC, which is based on holography [9]. With this method, it is technically possible to detect quality features of 100 % of the parts within the production process.

As it is assumed that there are no restrictions to the material flow, the procedure for the quality test has to consist of object recognition, alignment of the recognized object, extraction of features from the sensor data and comparison with the defined quality features. Within this process, the object recognition an alignment represents the interface between the manufacturing and the quality test process. This step can be performed by suitable handling techniques, e.g. micro robots, including image processing.

5 Planning of Micro Process Chains

A manufacturing process chain describes the chronological and logical order of all operations necessary to produce the component or subassembly. Due to the complexity of planning constraints and the absence of standardized technology and interfaces in micro production, handling and test operations have to be taken into account at an early state of the production planning process in order to avoid later cost and time efficient adjustments. This means, that production technology, test and handling techniques should be developed simultaneously. Thus, possible adaption problems between production technology and handling operations including discrepancies in handling time can be detected early and bottlenecks can be found. Taking this into account, an *integrated micro process chain* (Fig. 2) is suggested to provide a basis for production planning in micro cold forming. It illustrates the interaction between manufacturing technology, handling and transportation and quality management. The idea of the integration of these main fields of a production process bases on the experiences gained in the CRC 747, an interdisciplinary research project. Processes in all three areas are in state of development and strongly depend on each other. Taking into account the fragileness of the micro parts, their relatively high adhesion forces and sensitivity to environmental parameters like temperature or dust, handling devices have to pick up parts directly from the machine tools. In general, standardized handling techniques cannot be used for these tasks.

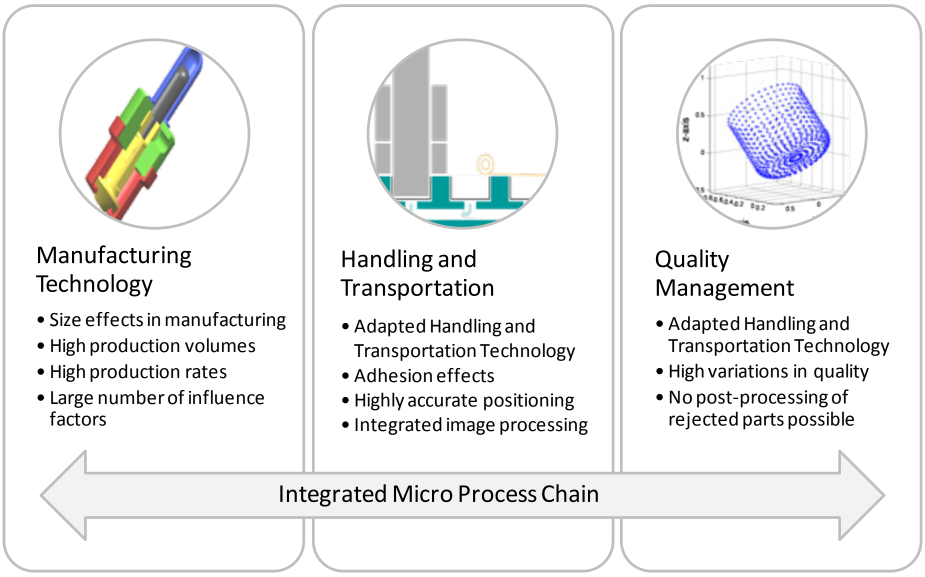

Fig. 2. Micro process chain integrating micro specific planning requirements in manufacturing technology, handling and transportation, and quality management

The planning of processes in micro cold forming requires a plan of material flow including details like the orientation of the part, whether or not the parts are transported individually or in a component carrier, or the production velocity. With simultaneous consideration of all theses parameters and the quality requirements and geometric features of the product, a suitable measurement technology has to be chosen, respectively developed. Project reality has shown, that even the (from a macro production point of view) obvious correlations and planning steps are not self-evident in micro production. Therefore, the focus of development cannot be restrained to manufacturing technology but must also be pointed to the interaction between machines, handling devices and measurement instruments.

6 Summary

We outlined the challenges in micro production with emphasis on handling and quality test operations. Due to high accuracy and a strong dependency between quality, handling and manufacturing in micro production processes, these three fields should be considered while planning and modeling micro processes. The proposed concept of the integrated view of micro process chain provides a framework for the generation of a planning tool kit for production planning with respect to specific characteristics in micro production. A modeling method which takes into account the correlations between the different parameters of all three areas will be the objective of further research.

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