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Regular Articles

A modular flexible scalable and reconfigurable system for manufacturing of Microsystems based on additive manufacturing and e-printing

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ABSTRACT

Digital manufacturing technologies [1] are gaining more and more importance as key enabling technologies in future manufacturing, especially when a flexible scalable manufacturing of small medium series of customized parts is required. The paper describes a new approach for design manufacturing of complex three dimensional components building on a combination of digital manufacturing technologies such as laminated objects manufacturing, laser and e-printing technologies. The micro component is made up of stacks of functionalized layers of polymer films. The concept is currently developed further in the project SMARTLAM [2,3], funded by the European Commission. The manufacturing system is based on a flexible, scalable and modular equipment and application features approach which enables the manufacturing of different small size batches without tool or mask making in short time. Different modules can be combined by defined hardware and software interfaces. Avoiding time consumable and difficult programming caused by manufacturing a new conceptual approach a Function-Block Runtime (FORTE) executes generated control application platform-independently and coordinates component module functionalities. The control system is designed to integrate all processes as well as the base platform with features far beyond ordinary PLC systems. One aspect is the use of process data out of the data acquisition system to simulate and optimize the processes. These results are incorporated into the main machine control system. Another aspect is the vision system for flexible quality control and closed-loop positioning control with visual servoing.

The paper shows the overall concept of SMARTLAM and exemplarily demonstrates the control system as well as the modular equipment approach by the example of the control system for alignment of different stacks and inspection system.

1. Introduction

Microsystems are gaining significant relevance in the European industries, according to recent marked studies [4]. However, the speed and degree of market introduction is tightly coupled to the development and improvement of design and manufacturing technologies. An overview on manufacturing technologies and materials, usage and application is given in Ref. [5] and [6]. The development of the markets in micro system technology shows that many new and innovative developments in the field of hybrid microsystems do not achieve a satisfactory success [7]. This can be attributed to the high complexity of micro-technical products and processes, a lack of interdisciplinary knowledge in process development, limited flexibility of the applied manufacturing and assembly systems and the high investment risk due to uncertain forecasts of growth [8]. SMARTLAM addresses these issues by introducing a flexible, modular manufacturing approach.

Modular micro assembly systems are often regarded as suitable link between the requirements of the market environment and the current state of development in micro production technology [9–11]. Approaches such as the Agile Assembly Architecture [10], Evolvable Assembly Systems [9] or Reconfigurable Micro Assembly Systems [11] are parts of ongoing research and have been partly

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transferred to commercial products.

Modular production systems are characterized by standardized components and defined interfaces [12]. The integration of process equipment into a machine concerns three domains: mechanical integration, supply of the process equipment and control integration. A modular platform, which is supposed to be easily reconfigurable, must provide thoroughly defined interfaces for all of these domains [13]. Compatibility between platform and process modules must be ensured.

The Agile Assembly Architecture as proposed by Rizzi et al. [14], is based on a large collection of mechanically, computationally and algorithmically distributed robotic modules which are referred to as agents. By thorough definition of mechatronic interfaces interoperability is ensured. The user of such a system shall be able to build a production system out of modules like building with lego blocks. This approach provides a high degree of flexibility and is highly scalable. Part of the philosophy is also a highly flexible transport system, which allows a free and multiple access to process stations.

This provides many advantages over the whole product life cycle. In the field of micro production these effects are particularly beneficial, due to the higher investment cost and higher complexity of the production equipment.

The design of microsystem products has to comply with the used manufacturing technologies in a 3D integrated manufacturing system. This requires integrating expert knowledge into the product design process, which is used to provide suggestions to the designer [15]. Feature-based design approaches, where manufacturing capabilities/technologies are mapped to 2D and 3D features were developed by [16] and [17]. Within the scope of SMARTLAM, these approaches were extended and adapted to cope with the specific technologies used.

Within the SMARTLAM project, a flexible, scalable and modular manufacturing environment, which is based on the layerwise construction of functional polymer film layers, is being developed. The design methodology for products, which can be manufactured by the SMARTLAM system, is based on modular building blocks having dedicated process chains for each functional element of the product (Fig. 1).

The specific instantiation of the digital manufacturing approach described in this document (furthermore called 3D-I (3D-integrated) production approach) facilitates the integration of single functional aspects, in three dimensions using a layer based design, to create products with higher level functionality [2].

Digital manufacturing platforms need to meet the challenge of staying competitive with traditional manufacturing systems [18]. Important key factors are extra costs, which emerge from complex hardware and software interfaces, as well as potentially rising idle processing times of single functional modules. A major goal of the SMARTLAM project is to improve competitiveness by designing products in an optimized matter, tailored to the used manufacturing technologies.

The flexibility provided by the digital SMARTLAM manufacturing platform supports agile product development following a logic similar to the iterative steps proposed by agile software development and agile manufacturing [19]. These scenarios apply for the envisaged SMARTLAM product types such as mass customized parts or any kind of flexible products.

In Smartlam, each iteration loop can be seen as a workflow consisting of four phases:

1. Plan (Product Specification and Design)
2. Develop (Design Support Tool)
3. Make (Process chain selection and Process chain configuration)
4. Analyze (inspection and process optimization loop)

Fig. 1. SMARTLAM enabling technologies.

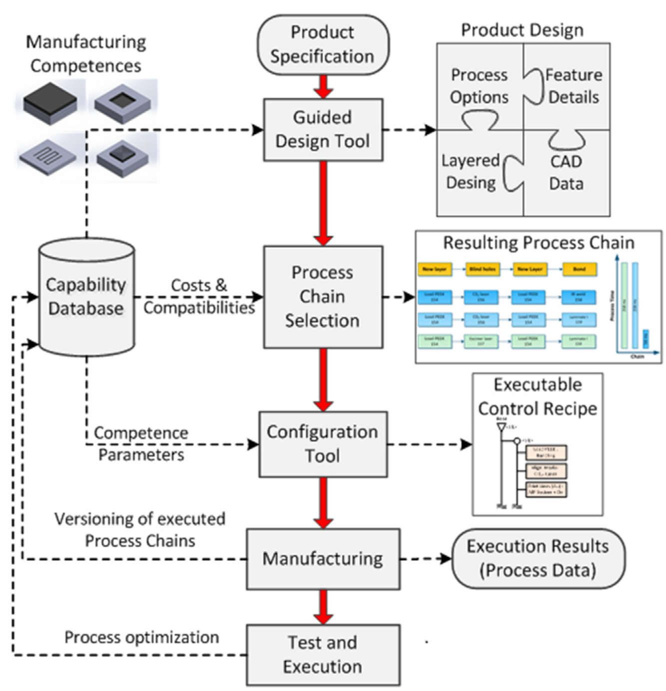

Fig. 2. Schematic overview of the 3D-I Manufacturing Approach.

Fig. 2 depicts a scheme of the workflow supported by 3D-I manufacturing approach. The process covers the whole manufacturing chain leading from a given product specification to production and product optimization.

The corresponding order planning approach is realized through a seamlessly integrated toolchain, which can be sorted along the layer model introduced by the International Standards for Automation (Fig. 3). ISA S95 is an international standard from the International Society of Automation for developing an automated interface between enterprise and control systems – an inherent part of the SMARTLAM project.