AUTOMATIC LEVELING AND LOADING PLATFORM FOR AUTONOMOUS PRODUCTION LINE

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Abstract: The following text aims to familiarize readers with the basic concepts and construction solutions of an autonomous production line using additive production to serve as a data source for research and development of industrial production systems and predictive maintenance systems. The first part deals with the conceptual arrangement of the modular autonomous production line and its components. Subsequently, the technical and construction design of the automatic platform of the autonomous 3D printer cell is described, which ensures the manipulation of the glass plate, which serves as a base-plate for the printed product.

Keywords: 3D printer, leveling, automatic production, heated bed, digitalization, automatic loader, MES, 3D farm, customized manufacturing, autonomous production cell, data collection, predictive maintenance

1 INTRODUCTION

For more than a year and a half, the development team of the Industrial Automation Group at the Faculty of Electrical Engineering at the Brno University of Technology deals with modern industrial technologies linked to the trend of digitization. As part of their innovation project aimed at bringing these technological trends to students and the general public, the focus was on production using additive manufacturing technologies. Among other things, several strategic partnerships have been established with leading players in this field, such as Siemens and the Institute of Production Machines, Systems and Robotics at BUT. Thanks to this connection and the ongoing efforts in the field of industrial production systems, the debate has also been opened up to production machines systems for data collection and analysis, dominated by the platform the MindSphere from the Siemens portfolio [3].

Thus, a discussion focused on the fulfillment of these systems with data has been opened up, that can be used to optimize production, predictive maintenance or production cycle management. Appropriate data for the development of these algorithms is undoubtedly data from a real-life production line, ideally operated at 100% of its capacity. The Institute of Production Machines has several professional high-quality production machines that make up a number of autonomous production cells and real production can be operated on them. However, these machines are disadvantageous for the development of predictive maintenance algorithms for several reasons. The first disadvantage is their performance and cost of maintenance. To fill the 100% capacity of these machines, it would be necessary to employ several people to care for trouble-free operation and supply these machines with a sufficient number of orders. Another disadvantage is its quality. Since the machines are made for commercial use and for 24 hours a day, 365 days a year operations, it is probably foolish to expect that machines will have frequent events that can be detected and used to generate predictive maintenance requirements.

Finally, it has been found that for the acquisition of data for the development of algorithms it will be ideal to use four low-cost thermoplastic 3D printers currently used by the development team for prototype or end-product production as well as for educational purposes. Since the goal of the project was to obtain as much data as possible, and the operation of contemporary thermoplastic machines is highly time-consuming, the concept of an autonomous production line (autonomous 3D farm) was born, which consisting of several autonomous production cells and logistical and supply system for handling with material and manufactured products. The advantage of the implementation of this concept is again the possibility of deploying a large number of technologies connected with the digitization trend and the utilization of the implemented line both as a data source and also as a teaching aid or testbed.

The first chapter describes the basic concept of the autonomous production line of additive production, which describes individual modules and the hierarchical distribution of control and connection to production control systems or data collection. The second chapter deals with the problem of the automatic start of product production and calibration of the first layer, which is crucial for quality and reliable production. The final part describes the following steps which will be taken in the near future for the successful completion of the project.

2 CONCEPT OF AUTONOMOUS ADDITIVE MANUFACTURING PRODUCTION LINE

The following chapter attempts to outline the concept of an autonomous production line for additive manufacturing.

The concept strives to maximize the idea of digitization while minimizing the requirements for maintenance of the entire line. More about the innovative approach associated with digitization can be read in [1]. Ideally, the line is capable of working independently, the only requirements for the operator are to maintain the stock of materials, glass base-plates and empty the finished product buffer. Each autonomous production cell will be implemented as a cyber-physical system, a system whose behavior is defined by both the cybernetic and the physical part. Cells are autonomous because of their ability to interact with the environment independently to ensure their maximum efficiency.

2.1 TOPOLOGY OF PRODUCTION LINE

The topology of the production line can be seen in the picture 1. All parts of the production line are bounded by a dashed line, which is composed of both autonomous and automated devices. These devices, as separate cells, are located along the track of a planar manipulator in a regular grid that, in combination with standardized cell size, allows the interchangeability of individual cells. Cells, depending on their construction, perform specific activities, the connection of which enables a fully automatic and autonomous mode of additive manufacturing.

We can divide the device into two types: support device and production device. It follows from the title that the production type device serves primarily for production (printing or machining), while the supporting type device serves primarily for the storage and handling of the material.

2.1.1 PRINTER MODULE

This autonomous cyber-physical cell belongs to a group of manufacturing facilities. It is a thermoplastic 3D printer capable of processing material in the form of filaments such as polylactide (PLA), polyethylene terephthalate (PET), acrylonitrile butadiene styrene (ABS) and copolyester (CPE). The cell is able to autonomously perform all the support activities that are needed to start and stop the production, and it is also designed to be able to monitor production progress and to check faultless performance. Other types of devices serve as support devices for this type.

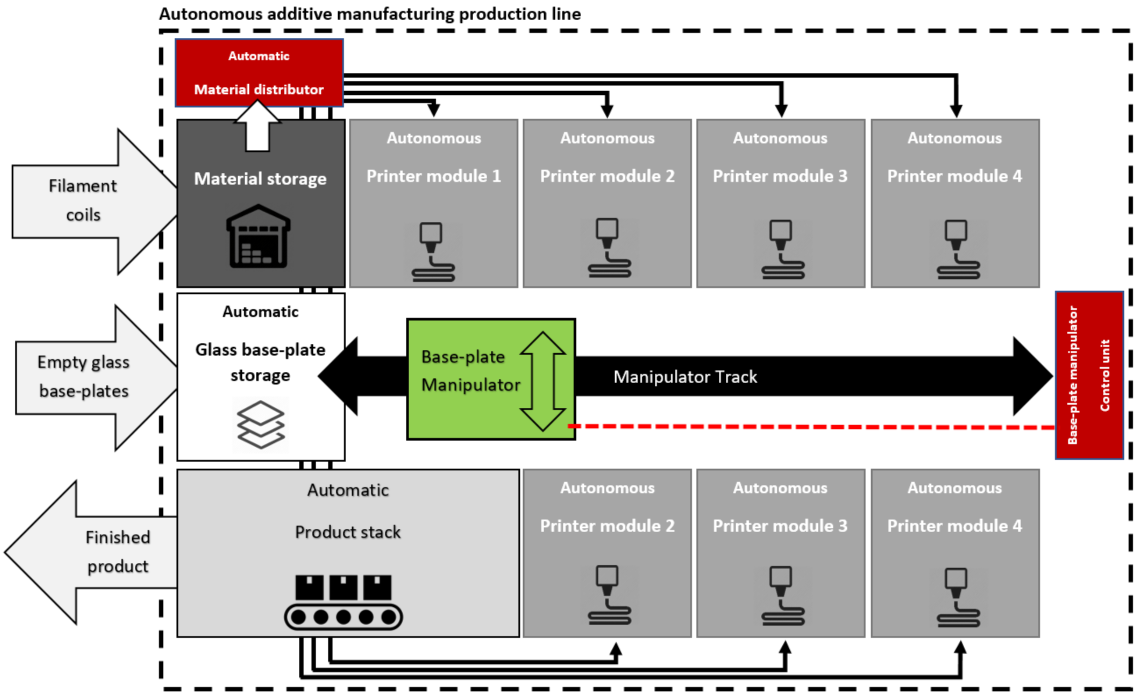

Figure 1: Topology of autonomous additive manufacturing production line.

2.1.2 Material storage module

This support cell serves as a material container for printer modules. In addition to inventory evidence logic, this cell is not equipped with any other systems. Material distribution between printer modules is realized through an automatic material distributor that distributes it to the printer space through the teflon tube. This system allows automatic filament settings and even automatic replacement if needed.

2.1.3 Glass base-plate storage module

This module is designed for storing the clean base plates of the glass on which the finished product is placed. This module allows the manipulator glass to be delivered to the production cell. The operator can also add clean glasses here. Part of the module could also be a baseplate washing line.

2.1.4 Product stack module

This module serves for cooling and storing finished products until they are picked up for further processing. Part of the module should be a marking and recording system allowing, for example, serialization of products.

2.1.5 Base-plate manipulator module

The function of this unit is exclusively handling the base plates of the products. This planar manipulator allows you to pick up the motherboard from the stock and insert it into the printer module. This unit also works in a fully autonomous mode.

2.2 Production line control hierarchy

The structure of the control system, unlike the conventional approaches of past industrial generations, does not have a precisely defined hierarchy. The concept of distributed intelligence is developed here on a large scale. Thanks to this, all participants are able to make decisions for themselves and meet their needs independently of the central control system. All participants are therefore equal and are allowed to negotiate access to resources autonomously. The Manufacturing Execution Systems (MES), which allows the assignment of orders to individual production cells, is part of the network. This system, developed by our team, is also meant to serve as a gateway for data gathering for analysis and for product lifecycle management.

3 AUTOMATIC LEVELING AND LOADING PLATFORM

The following chapter describes the development of a core element of an autonomous 3D printer for thermoplastics, which is an automatic platform for inserting the base glass, accurately seating it against the print head, and then unloading the finished product from the machine to the planar manipulator.

A very important element of this platform is the mechanism of leveling the pad against the nozzle. The quality of the first layer affects the result of the whole print in a very significant way. The height of the first layer significantly affects the adhesion of the print to the substrate. If the grip was low, the product would easily peel off during printing, otherwise, the product would be difficult to remove from the pad.

It is also important to fix the base pad, which prevents the product that is attached to the pad from moving to the printhead coordinate system.

3.1 Automatic loader platform

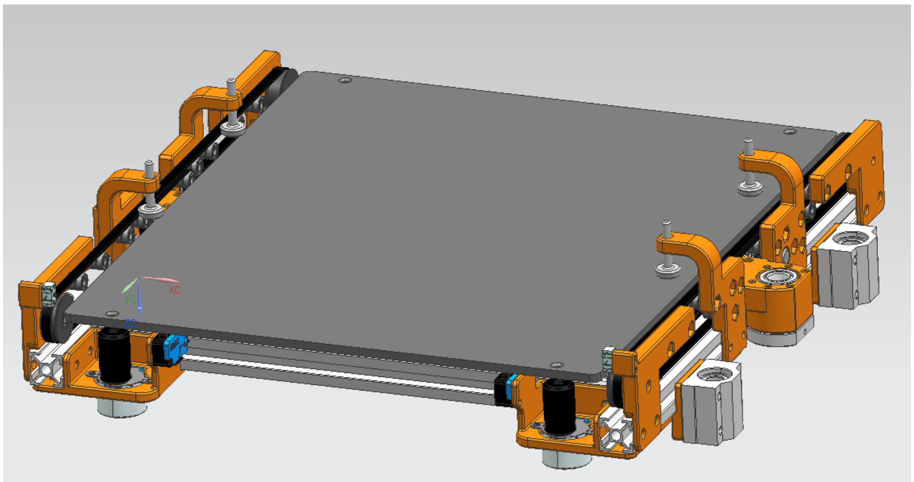

Figure 2: Automatic loading and leveling platform.

To solve all these problems, an automated platform for the thermoplastic 3D printer was developed and tested in the NX design system [2]. The platform replaces the heated bed of the printer and moves in the Z-axis using two ball screws and four linear guide bars. The complete platform can be seen in the picture 2.

The platform is equipped on both sides with rubber conveyor belts that allow the glass base plate to slide above the heated pad. Two end sensors are used to detect the base, if they are locked, the alignment of the base above the heated pad is confirmed. The heated pad is located on four helices, which allow independent height adjustment of each corner of the pad. The helices are driven by four stepper motors with a self-locking gearbox. When all four helices are lifted, the glass is lifted from the conveyor belts and, at the same time, it is pressed against the heated bed with 4 compression springs above the base to secure it in place. Subsequently, it is possible to move the sensor located next to the print head above the individual helix and, using the stepper motors, to place the base under the printhead in a plane. This setting occurs before each print, which ensures precise alignment of the first print layer, allowing for reliable printing.

A control system located below the platform is designed to control the drive of the washer. It is connected to the superior autonomous cell system via the RS485 interface and the Modbus protocol, which provides easy access to all functions.

4 CONCLUSION

Currently, the development of a system for collecting data from autonomous cells and the development of an autonomous cell of the 3D printer are underway. The concept that has been described in the first part of this document is gradually being incorporated into both developed elements. The current goal is to make these two elements operational by the end of June this year, and nothing prevents the start of data acquisition to develop analytical predictive maintenance and optimization algorithms.

As part of this project, several partial goals have been achieved, such as the virtual launch of an automated platform and the design of control electronics for its control. The next steps will be the realization of this platform and the design of the mechanical construction of the guiding system for the printhead. Then the launch of an industrial computer that will serve to manage an autonomous printer.

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