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CONCEPTION AND DESIGN OF THE DISCRETE MANUFACTURING PROCESSES CONTROL STATION

Abstract: This paper describes the concept of operation and organization of the automated discrete manufacturing processes control station, which is designed for research and teaching purposes. Station allows carrying simulated manufacturing process in the system consisting of machines, storage and transport system. The control system enables scheduling and routing of manufacturing processes, control over flow of single parts or groups of parts through machines, setting operating parameters of machines, fault and breakdowns simulation, acquisition of data on production process and analysis of system performance in SCADA and MES software.

1. Introduction

The discrete manufacturing processes control station is a part of the Discrete and Continuous Process Control Laboratory in the newly organized Scientific and Didactic Center of New Technology in Gliwice. This laboratory should enable the wide-ranging research and teaching in the field of control, automation, reporting, and optimization of production systems. In order to accomplish this task it is necessary to use one of commercially available training production systems [1, 2] or create custom project of the station [3]. Due to the high costs and insufficient flexibility and functionality of commercial solutions [4, 5] , it was decided to create an original concept of the discrete manufacturing processes control station. The station will consist of three main parts: hardware (mechanical design, drives and actuators), control systems (PLC controllers, sensors, drives, HMI, communication systems) and software part (software for scheduling, HMI/SCADA , database, MES and the necessary drivers). Parts (objects of simulated manufacturing) passing through modules of the station may or may not change its dimensions or features during the passage through station.

Software part of the station should allow setting of the work plan and schedule of the production system, monitoring of simulated production and analyses of different aspects of production system operation. [6].

2. Requirements concerning functionality

Modern manufacturing systems must meet the different and often conflicting requirements such as flexibility (simultaneous or sequential production of various products, individually or in lots of different sizes), high efficiency and reliability, while reducing manufacturing costs, reducing waste and improving working conditions. Computer systems plays the increasingly important role of in the integration and analysis of the operation of the production system in real time or with minimal delay. Planned station is intended to perform multiple functions, related to both research and teaching, which can be assigned to three main groups:

- Production planning and control – control algorithms of complex production and transport systems, planning and scheduling of production (including reaction to disturbances, and rescheduling) [7].
- Acquisition, reporting and analysis of production data – automatic acquisition of data on operation of individual stations and the entire production system, the means and methods of data acquisition (sensors, automatic identification systems, etc.), synthetic indicators of efficiency (OEE), activities related to maintenance of production system, flow of data and operation instructions, manufacturing execution systems (MES) [8], various forms of access and presentation of production data (reports, client applications, webservers, mobile devices), manager dashboards [9].
- Control systems, PLC programming and integration of production equipment – PLCs, HMI/SCADA systems, manufacturing data archiving, integration of devices and communication networks, OPC and MTConnect standards, etc. [10].

Scheme of planned hardware and software modules of the station and its connections are shown on Fig. 1.

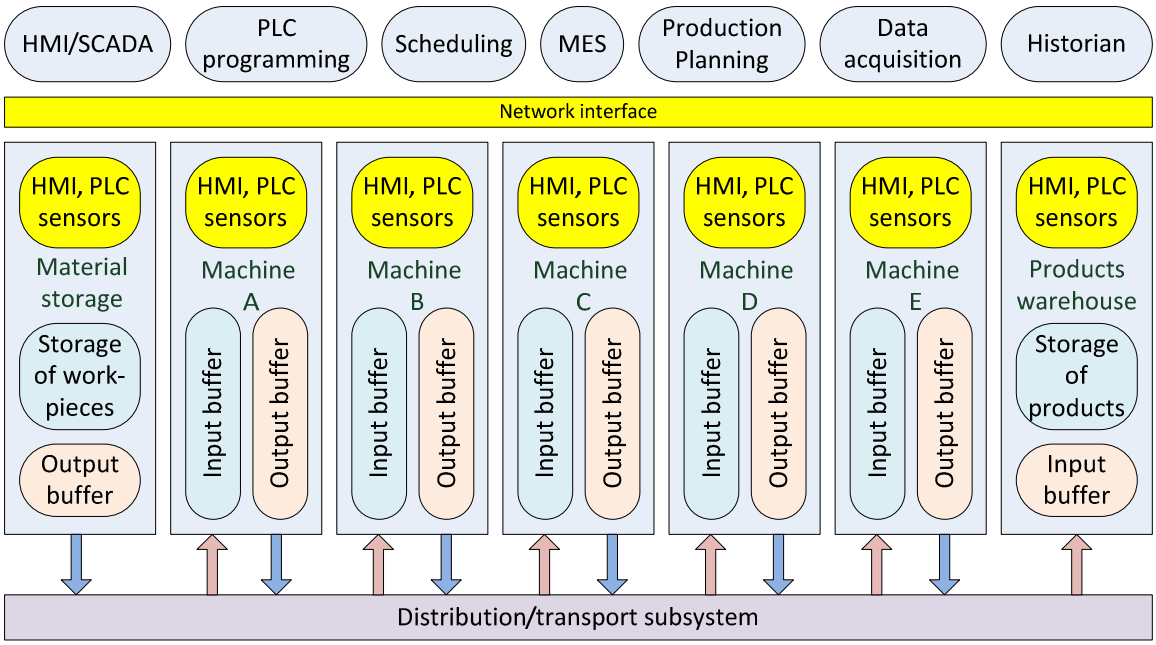

Fig. 1. Conception of discrete manufacturing processes control station

3. Conception of the discrete manufacturing processes control station

Because the station is designed to simulate operation of a complex production system, it should be built as a set of at least 4-5 modules simulating operation of machines, and storage modules for stock and products, connected to an automatic distribution and transport module. It is planned to set machines and magazines concentrically around the distribution and transport module, allowing for the movement of objects between any of the modules. All modules should be automated and equipped with PLCs, including communication interfaces and user interfaces (HMI), e.g. touchpanel displays.

Objects which are to move through the production system can be barrels or cubes made of various materials (plastic, metal), with a maximum height of 20 mm and dimensions: barrel – diameter 40 mm), rectangular – 40 x 40 mm. Their movement is obtained using a small belt or chain conveyors, e.g. products of Flexlink [11] with appropriate electric drives. Pushing objects between conveyors (e.g. input and output buffers of machine modules) and ejecting of objects from the input warehouse can be performed using a small pneumatic actuators. The whole station will be based on an aluminium chassis.

Fig. 2 shows the proposed layout of the discrete manufacturing processes control station, consisting of five machine modules (with separate local input and output buffers), input and output storage modules, and distribution and transport module (or alternatively – industrial robot).

The transport system connecting all modules (machines and storages) should allow moving items (single or sets of elements) between any of the machines according to the program. The number of items in batch, sequence and duration of operations and other parameters of production order are to be controlled from a local HMI device or remotely using HMI/SCADA software installed on workstations connected to intranet. These features allows the full simulation of the operation of a discrete manufacturing system.

Machine modules

Machine modules should allow simplified simulation of manufacturing operations, according to basic parameters, such as set-up time and machining time. Simulation of errors, downtimes and disturbances in operation of the machines, including machine parameters such as MTBF and MTTR, should also be possible. Each machine should be controlled by an individual PLC and equipped with necessary drives (input and output buffers – chain conveyors), actuators (e.g. pushing items from input to output conveyors) and sensors (detecting items in buffers and the state of actuators). State of the machine and production order realisation should be presented with a set of light signals or on the HMI panel, which is also used to set local parameters and generate disturbances.

The machine module can physically carry out activities simulating technological operations (e.g. drilling) or just keep the object in its workspace for a defined period of time (machining time). The machine will be equipped with input and output buffers, implemented as two parallel conveyors that can accommodate a certain number of items. Completion of technological operation is reflected by moving the item from the input buffer to the output buffer using actuator. Acquisition of production data from the machine is possible thanks to sensors, control systems and additional components, such as automatic identification (barcode readers, RFID and vision) systems – in case when machine will be equipped with these systems and objects simulating product will be appropriately labelled.

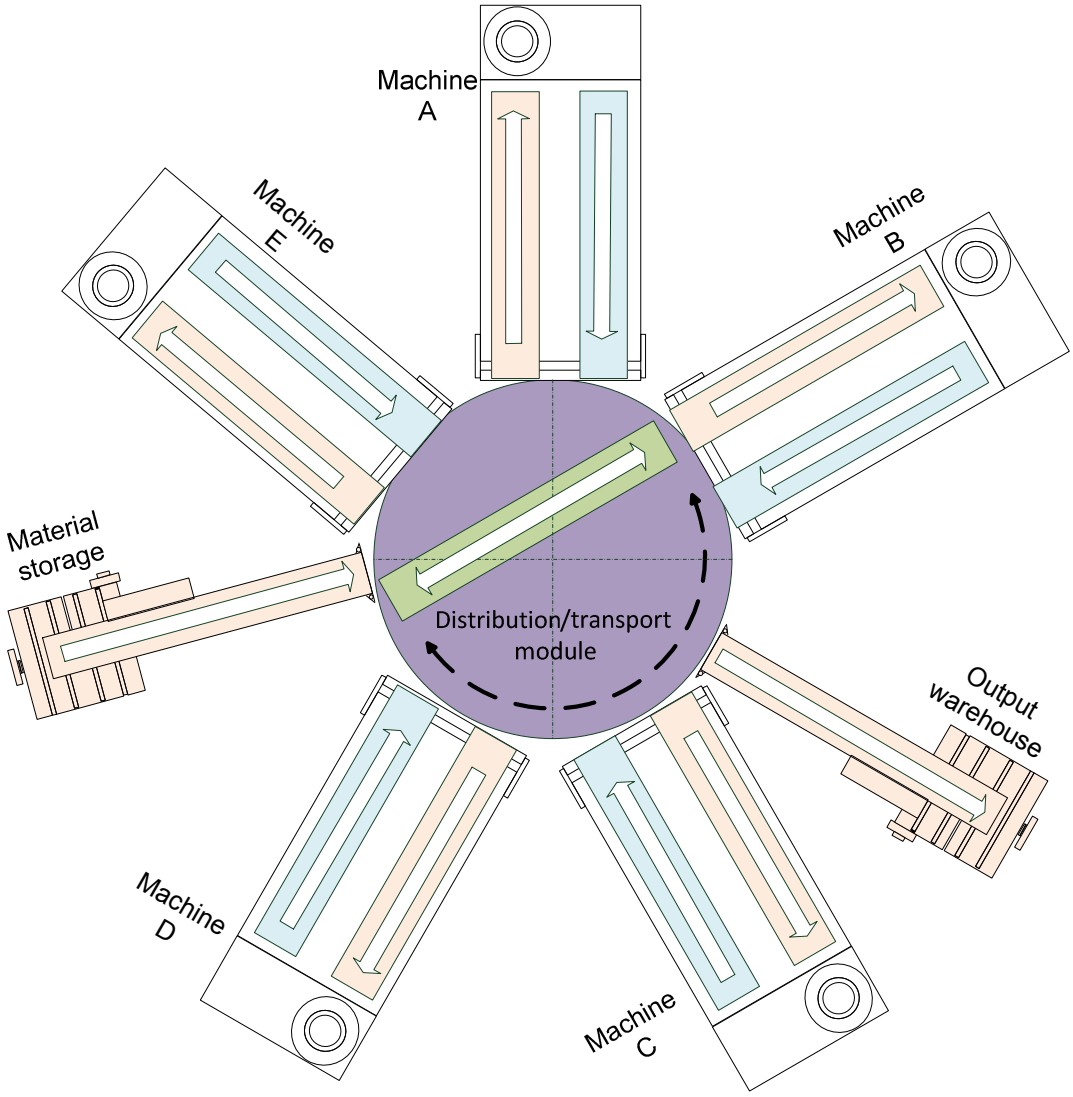

Fig. 2. Proposed mechanical layout of discrete manufacturing processes control station

Distribution and transport system

The basis of the transport system, allowing independent movement of objects between any module of the station is the distribution and transport module, implemented in the form of a centrally-located module with chain conveyor mounted on the rotating base. The conveyor has the same width as the conveyors constituting the buffers of machines and storages. To support both input and output buffers of machine module, the conveyor is installed with offset from the axis of rotation and can move in both directions.

A mechanism for advancing the conveyor to the machine and storage buffers was designed, allowing closing the gap between devices. The operation of these mechanism is shown in Fig. 3 - the upper and lower part of the figure shows a distribution unit at different positions, allowing connection with the input and output buffers of the machine module.

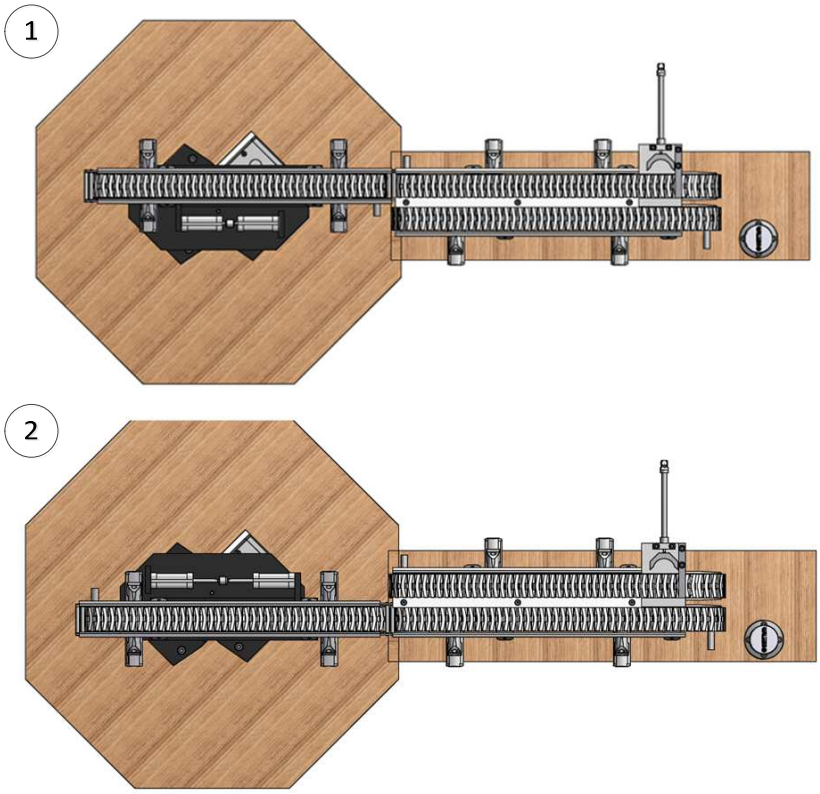

Fig. 3. Cooperation of the distribution module with machine module

Material (input) storage, products (output) storage

Input storage module should provide introduction of single objects or batches of a given number of items into the production system and should be fitted with an adequate set of data acquisition elements. The main element of the storage module is a vertical warehouse, from which the elements are pushed by the actuator on the chain conveyor, allowing forming batches of items and connection storage module with distribution module.

Output storage module is responsible for collecting of "finished" products from the production system, it is based on an chain conveyor carrying items into the basic container. Output storage module should be equipped with sensors detecting and counting various items.

Visualization of the discrete manufacturing processes control station is shown in Fig. 4.

4. Conclusion

The proposed discrete manufacturing processes control station by design and carefully selected components should allow the realization of expected functions better than the commercial systems thanks to ability to adaptation to the wide variety of research and teaching issues. A preliminary cost calculation based on the project of mechanical systems and control systems indicates that this functionality will be achieved at a lower cost. The use of modern control systems and standard interfaces allows its further development and adaptation to changing needs.

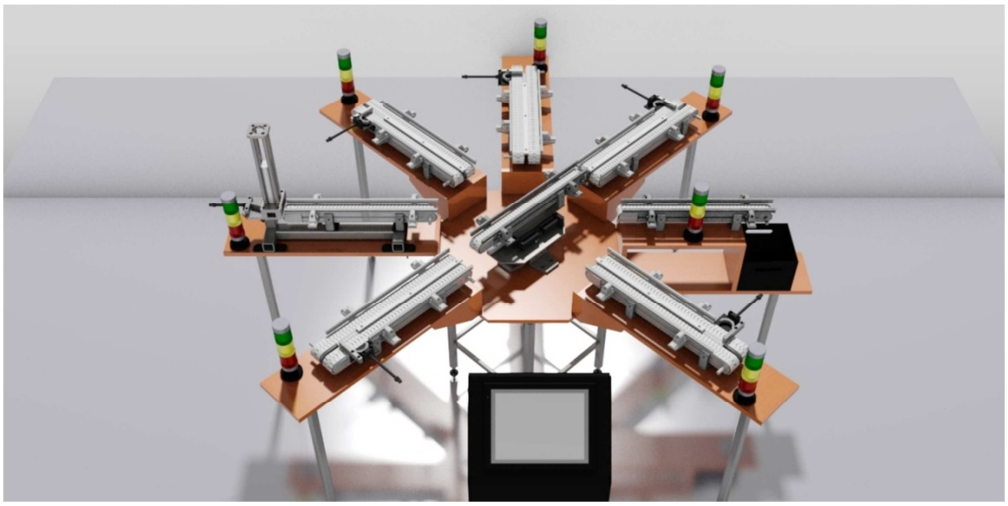

Fig. 4. Visualisation of the discrete manufacturing processes control station

References

1. Festo MPS The Modular Production System: www.festo-didactic.com/int-en/learning-systems/mps-the-modular-production-system/ [access: 11.06.2013].
2. SMC FMS-200: www.smcpneumatics.ie/pages/products.php?itemId=1240 [access: 11.06.2013].
3. Ćwikła G.: Stanowisko akwizycji, analizy i prezentacji danych z systemu produkcyjnego. Studia i Prace Kolegium Zarządzania i Finansów. ZN SGH, 116/2012, s. 59-69.
4. Świder J., Hetmańczyk M.: Hardware and software integration of mechatronic systems for an example measurement path for temperature sensors. Solid State Phenomena, vol. 147–149 (2009), pp. 676–681.
5. Świder J. (red.): Sterowanie i automatyzacja procesów technologicznych i układów mechatronicznych. Układy pneumatyczne i elektropneumatyczne ze sterowaniem logicznym (PLC). Wydawnictwo Politechniki Śląskiej, Gliwice 2008.
6. Ćwikła, G.: Elementy i systemy umożliwiające pozyskiwanie, analizę i prezentację danych produkcyjnych [in:] Knosala, R.: Innowacje w Zarządzaniu i Inżynierii Produkcji, Tom I. Oficyna Wydawnicza PTZP, Opole 2012, s. 780-789.
7. Grabowik C., Kalinowski K.: Object–Oriented Models in an Integration of CAD/CAPP/CAP Systems. LNAI 6678. Springer, vol. II, 2011, pp. 405–412.
8. Ćwikła G., Kalinowski K.: Proficy Plant Applications jako przykład oprogramowania klasy MES, [in:] Knosala R. (ed.) Komputerowo Zintegrowane Zarządzanie. Zbiór Prac, Tom I. Oficyna Wydawnicza PTZP, Opole 2008, s. 212-221.
9. Ćwikła G.: Manufacturing data acquisition in non-automated production systems, [in:] Kaźmierczak J. (ed.): Systems Supporting Production Engineering. Wydawnictwo P.A. Nova, Gliwice 2013, pp. 63-76.
10. Kaczmarczyk M., Kalinowski K., Ćwikła G.: Zastosowanie oprogramowania HMI/SCADA Proficy iFIX w sterowaniu zautomatyzowaną linią montażową, [in:] Knosala R. (Ed.) Komputerowo Zintegrowane Zarządzanie, OW PTZP, Opole 2009, s. 471-480.
11. Flexlink conveyors: www.flexlink.com/en/offering/conveyor-systems [acc. 9.09.2013].