THE DEVELOPMENT OF A FLEXIBLE ROBOTIC MANUFACTURING CELL

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Rezumat. *Această lucrare își propune să prezinte o soluție constructivă de implementare a unui grup de roboți industriali în cadrul unei celule de fabricație flexibile, cu destinație educațională. În demersul de reconstituire a celulei, din lipsa documentației necesare, s-au realizat procese de identificare ale principiilor de funcționare a elementelor constituente. Prin exploatarea celulei de fabricație, se urmărește reconfigurarea acesteia în scopul optimizării performanțelor în raport cu avansul și noile direcții ale industriei manufacturiere. Scopul final este înțelegerea și îmbunătățirea unei celule CIM, dar și redactarea unor resurse educaționale ce vor fi folosite în cercetările ulterioare.*

Abstract. *The aim of the paper is to present a constructive solution to implement a group of industrial robots in a flexible manufacturing cell for educational purposes. In the process of refurbishing the cell, due to the lack of necessary documentation procedures were carried out to identify the operating principles of the constituent elements. By exploiting the manufacturing cell, the aim is to reconfigure it in order to optimize its performance in relation to the new directions of the manufacturing industry. The goal is to understand and improve a CIM cell and to write educational resources to be used in further research.*

Keywords: CIM, Reverse Engineering, Manufacturing

1. Introduction

CIM (Computer Integrated Manufacturing) is a system that utilizes computers and software to integrate various manufacturing processes. CIM aims to streamline and automate the entire manufacturing process, from product design and planning to production, inventory management and quality control. By automating tasks and providing real-time data, CIM enables better control and optimization of flexible robotic manufacturing cell processes.

A flexible robotic manufacturing cell represents a versatile production system that incorporates robots, automation technologies and integration with other systems.

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Flexibility represents the key component which enables the capability to manufacture different part variants therefore, production quality can be adjusted quickly in response to changing demand.

2. Industrial Robots included in manufacturing cell

The manufacturing cell incorporates two Mitsubishi industrial robots: Melfa RV-E2 (Fig. 1) and Melfa RV-E3J (Fig. 2). Both robots belong to the same family but have different degrees of freedom, with the RV-E2 having 6 and the RV-E3J having 5. They share similarities in terms of repeatability, maximum composite speed, and positioning system. The RV-E2's additional twist axis offers greater flexibility but reduces structural rigidity and operational radius compared to the 5-axis RV-E3J.

Originally, the robots were used cooperatively for loading/unloading and pallet handling. The project aims to modernize their functionality and better integrate them with modern hardware. The controllers required cleaning and maintenance to restore their functionality. One controller was brought back online by cleaning circuit boards and addressing connectivity issues. The teach pendants, with basic electronics, remained functional and allowed program creation, editing, parameter entry, and homing.

Off-line programming was studied using the *Cosimir* integrated development environment, enabling graphical and textual programming. The robots' I/O blocks, which are mechanical relay-based, were explored for event timing and external stimuli reactions. By applying an external voltage, the I/O boxes responded correctly. This allows for more flexibility in programming and design, reducing dependence on a separate PLC system.

Fig. 1. EV-E2 Industrial Robot.

Fig. 2. EV-E3J Industrial Robot.

3. The pneumatic system

The Transfer/Transport System features an electronically controlled pneumatic system comprising 5/2-way mono-stable electro valves, small pneumatic cylinders, and pressure regulators (Fig. 3). The cylinders, controlled by the electro valves, position and stop the pallet-carrier at the workstation.

Fig. 3. 5/2-way mono-stable electro valve.

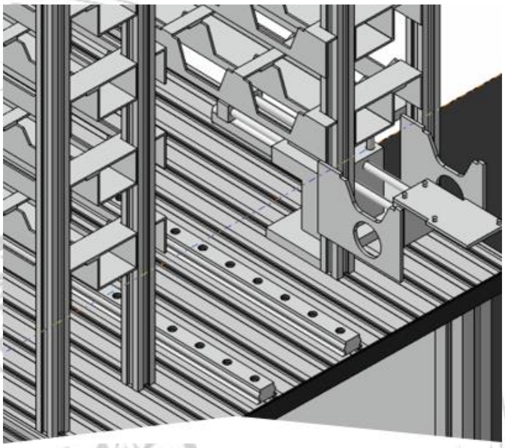

Fig. 4. Pallet loading/unloading system.

Connected to the Transfer/Transport System is the automated rack. The pallet carrier is positioned at the front of the rack (Fig. 4) and lifted to the loading/unloading system. The pallet is then transferred into the rack using a pinion gear mechanism. The Load/Unload System consists of two pneumatic cylinders, two 5/2-way mono-stable electro valves, and a pressure regulator. One cylinder moves the boom vertically, while the other enables axial movement to transfer the pallet from the carrier to the pick-up area. Electronic commands are issued by the rack's integrated PLC, with a working pressure of 2.5 bars.

Reprogramming the PLC has proven unfeasible due to lost means of programming. The rack's electronics are considered a black box, and efforts are focused on understanding the means of commanding it. The main interface is a 4-bit electrical I/O port, where logic level high voltages are applied to issue commands. Initial tests confirmed functionality, and a Python program was developed for automated command sending and initial position indexing. Further research is needed, but time constraints limit exploration.

The pneumatic cylinders' gaskets have worn down and become brittle over time. While the cylinders functioned during testing, pressure loss occurred after several cycles. Replacement efforts for the cylinders are underway, but the possibility of replacing the rack's pneumatic system with the 5-axis industrial robot has been considered.

4. Electronic components

The system includes specialized modules for pallet carrier detection and identification. This is achieved using an inductive proximity sensor to detect the carrier's presence and a capacitive identification sensor to read a unique identifier from a plastic tab. These sensors interface with local-control modules, transmitting signal information to the main PLCs via the RS-232 bus. Reverse engineering the sensors and control centers involved connecting a logic analyzer to identify the protocol and data structure used (Fig. 5).

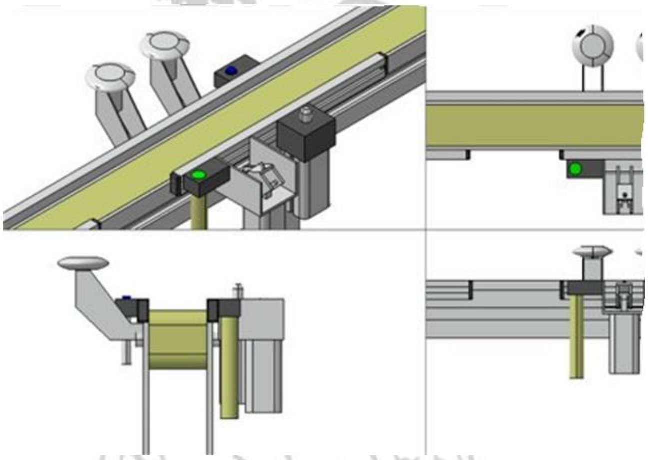

Fig. 5. CAD model of the electronic components.

5. Configuring the cell

The process of configuring a CIM cell involves a series of iterative steps that have been analyzed and evaluated to achieve a balance between productivity and accessibility. The process requires careful consideration of various factors and parameters to optimize the overall performance. During each iteration, the aim is to adjust and reorganize the arrangement of the machines, tools and other technologies within the cell.

5.1. The production focused approach

This configuration approach places a strong emphasis on optimizing the utilization of available space, minimizing cycle time, and reducing the number of active components involved. By carefully considering the spatial arrangement of machines, tools, and automation technologies within the CIM cell, the goal is to make the most efficient use of the available workspace. This not only ensures that the equipment is effectively utilized but also enhances the overall productivity of the cell.

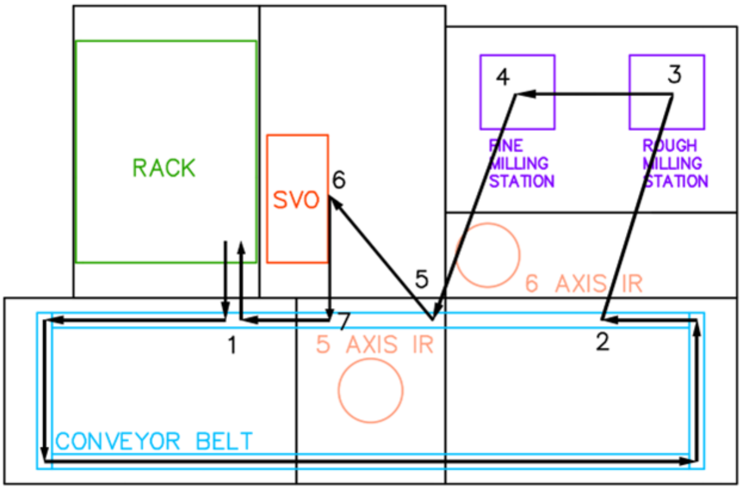

Fig. 6. Production focused approach cell workflow.

The CIM cell follows a specific sequence of steps to carry out its operations efficiently. These steps involve the storage and transportation of raw materials, movement of materials across the table using a transport or transfer system, processing of materials by one robotic arm through rough milling and fine milling operations, inspection of the processed material by another robotic arm using an optical verification system (SVO), transfer of material to conveyor belts for transportation, and finally, indexing of the processed pieces in the rack for organized storage (Fig. 6). These steps together form a well-coordinated workflow within the CIM cell, enabling smooth material processing and handling (Fig. 7).

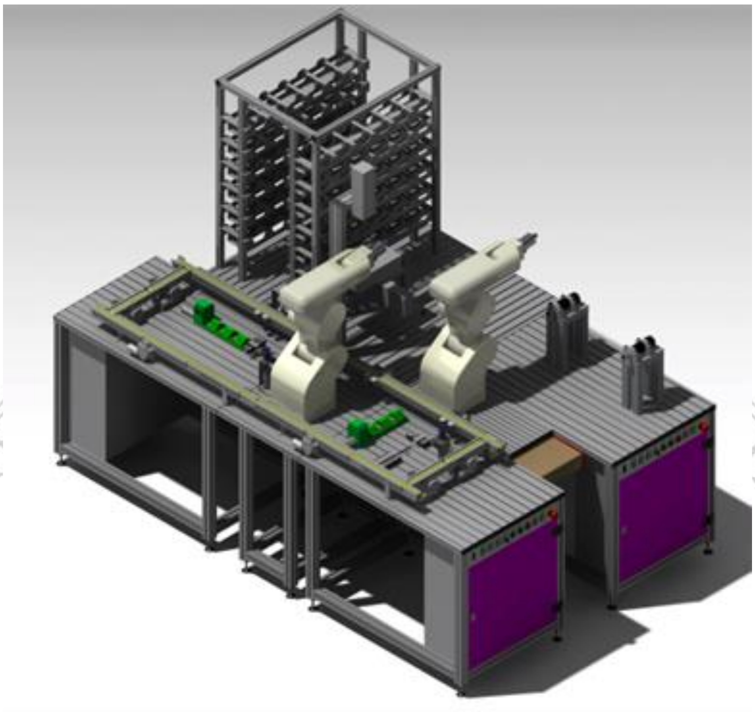

Fig. 7. Simulated design for production approach

5.2. The education focused approach.

The design and development of this other configuration was focused on the educational part. The system is separated in modules, which can be used independently from each other (Fig. 8).

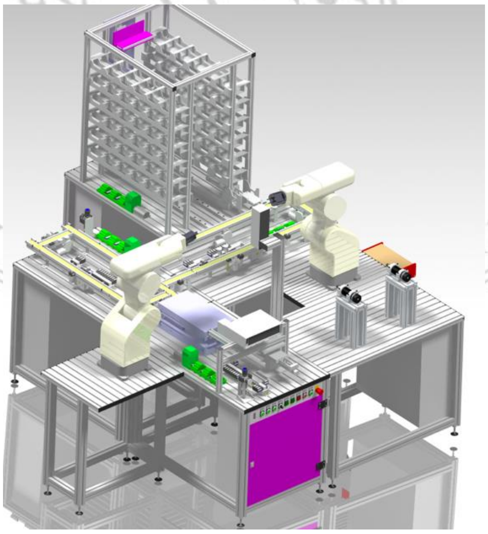

Fig. 8. Simulated design for educational approach

6. Conclusions

Through the reverse engineering process, progress has been made in understanding and successfully working with various systems and components of the cell. Currently, the robots, optical verification system, and pneumatic components are fully functional. The remaining task is to determine how to control the stack.

Further efforts involve documenting the research findings, considering the primary educational purpose of the CIM. Additionally, a new and adaptable fabrication system is being developed, leveraging the accomplishments made so far. The goal is to create an application that serves educational purposes, reviving a valuable but abandoned piece of technology.

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