SCHOOL OF ENGINEERING

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MNFG309: INDUSTRIAL ROBOTICS AND AUTOMATED ASSEMBLY

Problem-Based Assignment–Robotic Cell Design

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Declaration

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1. Outline of the Task

1.1. Aim of the Task

Figure 1: Manual handling of a crates.

The video demonstrates the production process of injection molded crates, where the injection molding machine injects melted plastic into a mold to create a crate. After the injection process, workers manually open the machine door, remove the crate, and then manually trim die flash by using a knife on a rotatable table, before finally stacking the finished crates to one side. As shown in Figure 1, this process currently requires substantial manual labor, posing safety risks and low efficiency.

1.2. Main Intent of the Design

The primary purpose of designing this fully automated robotic cell is to enhance production efficiency and economic benefits, reduce labor intensity, and improve workplace safety. By integrating automated equipment, such as robotic arms and automatic cutting devices, aim to achieve unmanned operations, reducing errors and injury risks associated with manual handling, while also enhancing the continuity and consistency of production.

1.3. How the Task is Mechanized

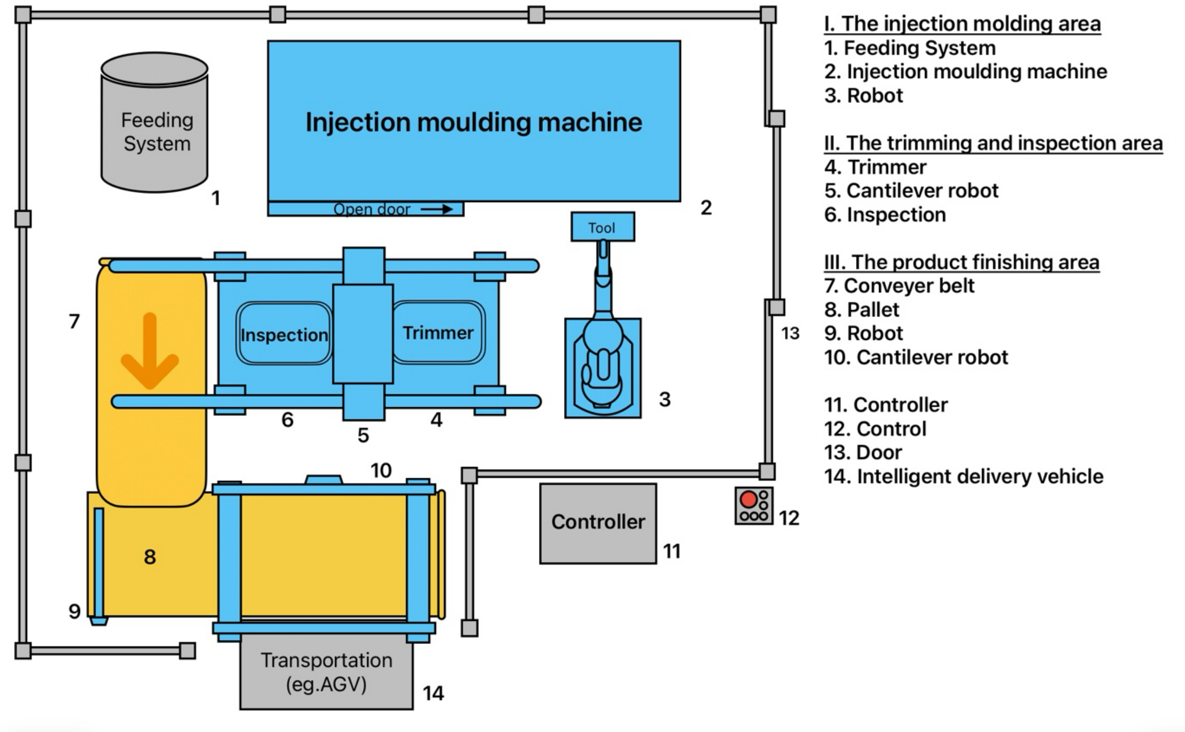

Figure 2: Robotic cell design.

Figure 2 visually displays the overall layout design, this robotic cell mainly includes three areas, with multiple mechanical devices planned to automate the process. The first area is the injection molding area, which includes a feeding system, the injection molding machine, and a robotic arm. The feeding system will transport the required materials to the injection molding machine. After the injection molding is completed, the tool at the front end of the robotic arm will take out the freshly made crates through the door that open on the injection machine, placing them in the trimming and inspection area to the left. This area primarily handles the trimming and inspection of the crates, with robots responsible for transporting crates from the trimming area to the inspection area and then onto a conveyor belt that leads to the product finishing area. The robot in the final area works with the conveyor belt to neatly arrange the crates and transfer them onto an intelligent distribution vehicle, such as an Automated Guided Vehicle (AGV), which then transports the crates to a storage area or other designated locations. Throughout the process, corresponding sensors and vision systems will be installed to ensure precision and safety of operations. All three areas are enclosed within fences, with a system control panel and a main control outside the fences, and a door located on the right side of the robotic cell.

2. Methodology for Automation

2.1. Automation Steps

The automation of the crate production process includes several key steps to ensure efficiency and safety. Initially, materials are supplied and molded, where the feeding system automatically transports plastic raw materials to the injection molding machine, where corresponding sensors or algorithms ensure the correct amount of material is delivered to maintain consistent crate quality. Following this, the crates are removed and transferred; once the injection process is complete, a robotic arm equipped with precision grippers extracts the crates from the mold. The design of this gripper depends on the shape of the crates. This arm is programmed to handle the crates gently to prevent damage and can adjust its gripping force based on the crate size detected by integrated sensors. The crates are then moved to a dedicated trimming station and placed into corresponding slots for die flash removal, where the automated cutting equipment removes any excess die flash, using high-precision blades or lasers guided by advanced vision systems to ensure accurate trimming and smooth edges. After trimming, a cantilever robot above this area transports the crate into inspection slots in the checking area, where another set of cameras and sensors perform quality assurance checks. Any crates that do not meet the predefined criteria will be left in the bin under the workbench for recycling. Finally, the approved crates are moved to the stacking area, where a specialized robotic stacking system arranges the crates in a predetermined pattern on a pallet. Once a pallet is fully loaded, it is automatically moved to the storage area or loaded onto an AGV for distribution.

As the entire process involves robotic replacements for previous manual operations, the door of the injection machine remain open throughout the process, eliminating the need for additional opening and closing actions to save consumption. The entire automated system operates within an enclosed fence, with gates that remain normally closed to prevent staff from accidentally entering the machine working area and causing hazardous incidents. Additionally, all positioning operations involved in the process are supervised by corresponding sensors and vision systems, with controllers outside allowing for the monitoring of each machine's operational status. The control in the corner contains a master switch, which can be used in emergency situations to control the system.

2.2. Supply of Parts and Waste Control

The raw materials required for the crates are stored in bulk bins near the feeding system, which uses a combination of conveyor belts and pneumatic systems to efficiently supply materials to the injection molding machine. Waste generated in the trimming and inspection area falls from the crate slots into the workspace below, where a vacuum suction system collects all the waste material generated during the die flash removal process. Consider grinding plastic waste into reusable particles, which can then be reintegrated into the raw material supply or used to make other items, thereby minimizing waste, and reducing production costs.

The entire process is controlled by a central management system that coordinates the operations of each component to optimize the flow of materials and finished products. This system also supports remote monitoring and troubleshooting, ensuring minimal downtime and maximum productivity. These automation steps and systems not only streamline the entire production process but also enhance the operation's safety and environmental sustainability. By implementing these technologies, the factory can achieve higher throughput rates while maintaining strict quality standards and reducing reliance on manual labor.

3. Develop Chosen System

3.1. Safety Systems

Safety is paramount in the design of any automated industrial environment. The robotic cell in this design includes multiple safety systems to protect both the machinery and the operators. Intuitive is safety fence surrounds the entire robotic unit to prevent unauthorized personnel from entering during operation. This barrier is crucial for ensuring that the robots' high-speed movements do not pose a danger to humans. Additionally, emergency stop buttons are located outside the fencing and at the control station, allowing for the immediate shutdown of all robotic operations in the event of a safety issue or malfunction. This is beneficial for preventing accidents and facilitating safe maintenance and troubleshooting. Additional sensors within the unit detect any anomalies or potential safety hazards, automatically pausing operations to prevent damage or injuries. These systems form an integrated network that is monitored and managed through a centralized control system, offering a seamless operational flow and the ability to quickly respond to any system alerts or faults. This comprehensive approach to automation, coupled with strict safety measures, establishes a robust and reliable production environment.

3.2. Robot Specifications

The automation of crate handling and processing tasks is accomplished using various types of robots, each selected based on the specific functionalities required for different operations within the unit.

a. High-payload robotic arm.

To move crates from the injection molding machine to the trimming station, the designed robotic arms capable of handling payloads significantly heavier than the average weight of a filled crate. This arm is equipped with grippers tailored to the current crates and can adjust their gripping force based on the crates' size and weight, ensuring safe handling without causing damage.

b. Precision robotic arms for trimming.

Robotic arms equipped with high precision cutting tools are used within the trimming station slots. These robots are smaller and more agile, capable of making precise cuts to remove die flash. They are guided by vision systems that provide real-time feedback to ensure each cut is made accurately.

c. Cantilever robotic arms for handling.

Cantilever manipulators are used in two places in the design, the first one equipped with a gripper, which is used in the second area to transfer crates from the trimming slot to the inspection slot and then to the conveyor belt. The second cantilever robotic arm is located at the pallet in the third area, using a baffle to push neatly arranged crates from the pallet onto a delivery cart. In addition, a small robot is attached to the side of this cantilever arm; it has a simple structure with a small baffle acting as an arm. Whenever a new crate arrives on the conveyor belt to the pallet, it will moves forward quickly to push the crates, ensuring they are neatly arranged on the pallet.

d. Automated Guided Vehicle (AGV).

AGVs are deployed to transport finished crates from the stacking area to storage or another work area. These vehicles are programmed to navigate the factory floor autonomously, using sensors and maps to avoid obstacles and efficiently carry out their tasks.

4. limitations and Improvements

Although the current robotic cell design significantly improves efficiency and safety, it also presents several specific limitations that need to be addressed. The robotic cell is divided into three distinct areas, each designed for specific tasks, such as injection, trimming, and handling. This fixed layout may limit the system's ability to adapt to changes in production demands. The robotic arms and tools used in each area are specialized for particular tasks. While this specialization increases efficiency, it also reduces the versatility of each robot, which could lead to underutilization when product specifications change. Furthermore, the complexity of having multiple robotic systems working together increases the likelihood of mechanical failures and the need for frequent maintenance. The reliance on complex sensors and vision systems also introduces vulnerabilities, such as sensitivity to environmental factors like lighting and dust. Regarding space utilization and scalability, the cell's design requires a substantial footprint within the manufacturing facility, dedicating a large amount of space to each segment of the process. For example, the current feeding system is designed only for one injection molding machine. Consider integrating the feeding systems in a broad range of robotic cells into a large central feeding system, which would facilitate the management of raw materials and save floor space.

To mitigate these limitations and enhance the overall functionality and adaptability of the robotic unit, several improvements are considered. A more modular design could be adopted to allow for easier reconfiguration of the robotic cell, significantly enhancing its adaptability. This would enable quick adjustments to the layout and functionalities to accommodate different crate types or new production requirements. Additionally, investing in robots capable of performing multiple functions or easily switching between tasks could improve the operational flexibility of the unit. This approach would also enhance the return on investment by maximizing each robot's utilization. Consider redesigning the layout to make it more compact and efficient, which would help better utilize the available space and enhance scalability. This might involve integrating more advanced conveyance systems that occupy less space but offer greater efficiency. Future updates should also focus on improving energy efficiency, possibly through better power management systems or by integrating renewable energy sources, thereby reducing the operation's carbon footprint and operational costs. By addressing these limitations and considering these improvements, the automated system can be better prepared to meet future demands and challenges, ensuring long-term sustainability and effectiveness in an ever-evolving manufacturing environment. The ideal future layout is shown in Figure 3.

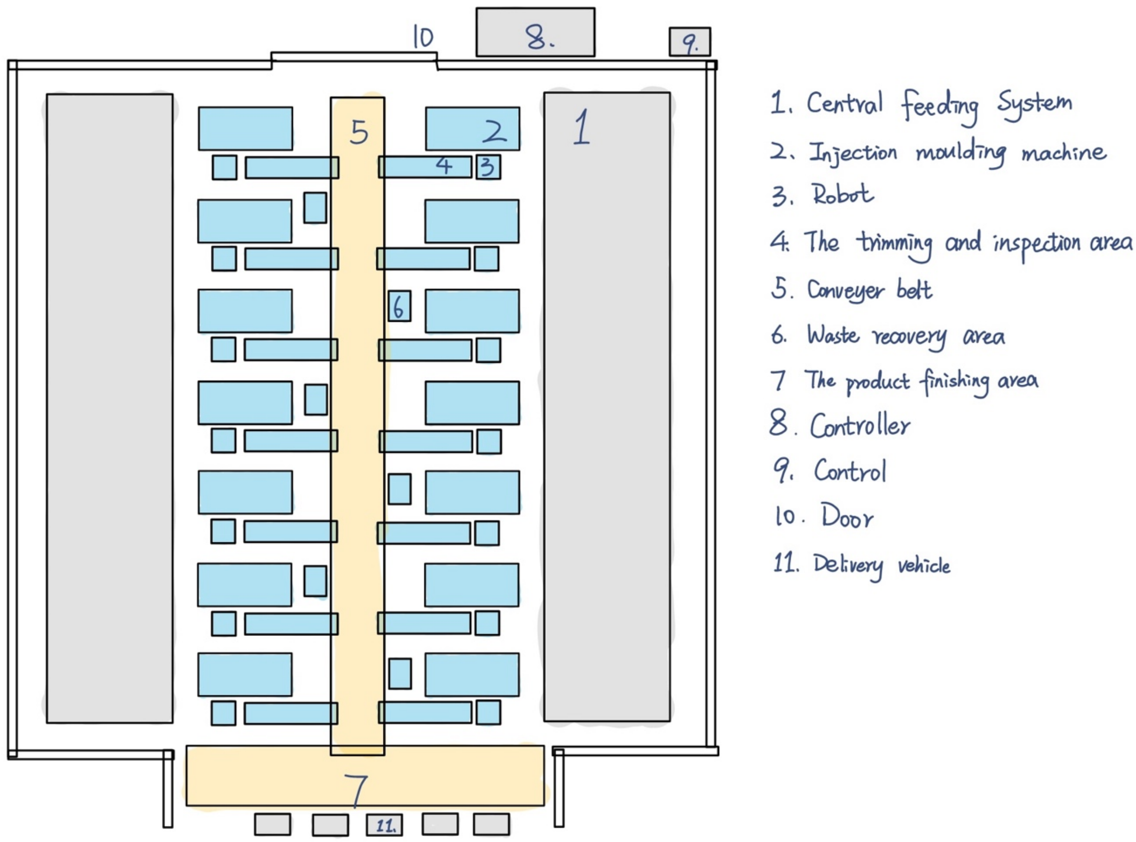

Figure 3: Future layout.