

University of Wales Trinity St David – School of Engineering

ACHA5001 – Automation Development and
application of manufacturing automation

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Contents

Section A

Part 1 - Introduction – Pages 1-2

Part 2 – Fixed automation – Pages 2-3

Part 3 – Programmable automation – pages 3-4

Part 4 – Flexible automation – Pages 4-5

Section B

Part 1- Flexible automation in flat pack furniture manufacturing
– Pages 5-6

References – Page 7

Section A -

Introduction to Manufacturing Automation

The origins and the development of manufacturing automation are notable examples of human creativity and the advancement of manufacturing efficiency. Following World War II, there was a global increase in industrial demand. However, this was combined with decreased labour shortages and a shortage of raw materials, presenting significant challenges to the industrial sector. Because of this, the first automation technologies were developed due to the need to address the shortfall in human labour, improve production efficiency, and reduce the costs associated with manufacturing. As time progressed into the 1970s, these initial developments evolved into a more industry-wide adoption of automation within manufacturing production. These advancements were critical in redefining manufacturing processes, marking a significant shift from traditional manual craftsmanship into the period of automated mass production. This transition was not a small one that was adopting new technology; it was a fundamental redesign of manufacturing methodologies, leveraging the precision, consistency, and speed now possible with automation technologies. This evolution was characterised by integrating robotics, computer-aided design (CAD), computer-aided manufacturing (CAM), and the introduction of artificial intelligence, which enhanced manufacturing efficiency and production quality. Using sensors and transducers, control systems, and sophisticated software programs enabled the automation of complex tasks, from the assembly line to quality control, minimising human error and optimising production timelines. This method dramatically improved how goods were produced; this era laid the groundwork for the advanced automation systems that characterise today's manufacturing landscape. These systems are more efficient and adaptable, capable of responding to changes in production demands and specifications almost instantly.

Types of Manufacturing Automation

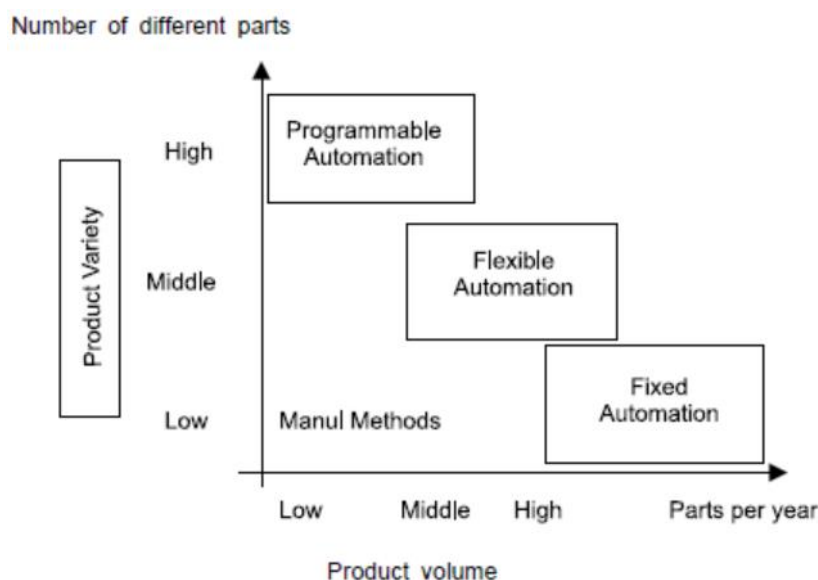


Figure 1: Diagram comparing different manufacturing automation strategies (Source: Control Freaks Ltd.,2020: online)

As shown above, in Figure one, there are three main strategies for automating manufacturing processes: fixed, flexible and programable automation, each of which has its advantages and

disadvantages, more specifically as shown by their relationship between the product volume that they can produce compared with the variety of the products that they can manufacture, and therefore applications that they are used in. Therefore, below, you can find a description of each of the three methods, their history, applications they can be found in modern-day manufacturing, their advantages and disadvantages and some information on the control systems that are used to manage them.

1. Fixed Automation (Hard Automation)

Historical Context and Industries

Fixed automation, also known as hard automation, first emerged in the early 20th century with the automotive industry's adoption of assembly line production techniques. Pioneered by Henry Ford, these techniques dramatically increased production rates and efficiency from their previous levels, serving as a precursor to modern fixed automation systems. A prominent example of where this is used in modern-day manufacturing is the automotive manufacturing industry. In the automotive sector, fixed automation is employed in various stages of the manufacturing process, such as assembly lines, welding, painting, and pressing operations. Robots and dedicated machinery are programmed to perform specific tasks with minimal variation. For example, in car assembly lines, robots are used for welding car body parts together, installing seats, and mounting tyres, all with precision and consistency. The equipment used in these processes is designed for specific tasks. It only adapts to changes in product design with significant reconfiguration or replacement, a characteristic of fixed automation's inflexibility. Fixed automation enables automotive manufacturers to achieve high efficiency, productivity, and quality levels. The automated systems can work 24/7 with consistent speed and precision, significantly reducing the likelihood of human error and increasing production output.

Advantages

The primary advantage of fixed automation is its ability to achieve production rates that cannot be met using different methods. Employing specialised equipment and tooling designed for specific tasks and to produce specific parts or products can guarantee a consistent and high-quality output. This automation type is characterised by its reliability and robustness. It also offers predictable operational costs and minimises human error.

Disadvantages

However, fixed automation's ridged and permanent nature is also a disadvantage and an advantage. The high initial investment in specialised machinery needed and the lack of ability to adapt to design changes of the part or product being produced make this type of automation less suitable for industries where product specifications frequently change. Additionally, the cost and time associated with retooling or modifying production lines can be prohibitive, limiting the system's applicability to high-volume, low-variety production scenarios and not allowing for any low-volume, high-variety production.

Control Systems and Process Variables

Fixed automation systems typically utilise hardwired control systems with minimal programming flexibility. These systems are designed to perform a specific sequence of operations with high precision. Process variables, such as conveyor speed, temperature settings, and timing mechanisms, are meticulously controlled to ensure optimal performance and efficiency and, therefore, remain constant over time, rarely changing. The control mechanisms in fixed automation are often custom-

designed for each application due to the specialist processes, requiring significant upfront engineering and design effort.

2. Programmable Automation

History and Industries

The introduction of programmable automation marked a significant technological leap in manufacturing technologies, introducing versatility and adaptability into manufacturing processes. The development of computer numerical control (CNC) machines in the 1960s and 1970s and the subsequent introduction of industrial robots revolutionised manufacturing production lines, allowing for rapid changes in production setups, tooling, and quick changes between the produced parts and products. A prominent example of how this is used in modern-day manufacturing is the electronics manufacturing industry. In electronics manufacturing, products have shorter life cycles and more frequent updates or variations than industries suited for fixed automation. Programmable automation allows for the quick reconfiguration of production equipment to adapt to new product designs or changes in product specifications. This is particularly important for producing circuit boards, smartphones, laptops, and other electronic devices, where product designs and technology evolve rapidly. Equipment such as programmable logic controllers (PLCs), robotic arms, and automatic guided vehicles (AGVs) are commonly used in this sector. These devices can be programmed to perform various tasks, such as assembling delicate components, soldering circuit boards, and handling materials. The ability to reprogram these machines and robots for different tasks allows manufacturers to switch between product lines with minimal downtime, thereby efficiently accommodating small batch sizes and custom orders. The flexibility offered by programmable automation in the electronics manufacturing industry supports the rapid pace of innovation and customisation demanded by the market, enabling manufacturers to maintain competitiveness and respond quickly to changing consumer preferences.

Advantages

Programmable automation's main advantage is its flexibility in the parts or products that it can produce. The ability to quickly reprogram machinery and equipment for different tasks and switch over tooling allows manufacturers to respond swiftly to market changes, customer demands or feedback from quality control or the consumer market. This adaptability reduces the lead time for product changes, reduces income loss, and enables a more diversified product portfolio. Furthermore, programmable automation minimises the reliance on manual labour for repetitive, dangerous tasks, improving workplace safety and efficiency.

Disadvantages

The flexibility of programmable automation comes at a cost. The variable costs associated with smaller production runs can be higher than those of fixed automation, primarily due to the need for skilled personnel for programming and maintenance and very specialised tooling for only a small run of finished parts or products. Additionally, the investment in software and control systems adds to the overall cost of implementing programmable automation.

Control Systems and Process Variables

Programmable automation relies on computer-based control systems that can be reprogrammed for various tasks. These systems, which include CNC machines, programmable logic controllers (PLCs),

and robotic arms, offer significant flexibility in adjusting process variables like tool paths, assembly sequences, and material handling procedures. The software-centric nature of these controls allows for rapid adaptation to new production requirements, albeit with the need for continuous updates and maintenance.

3. Flexible Automation

History and Industries

Flexible automation represents the most significant advancement of manufacturing automation, combining the efficiency of fixed automation with the programmability and adaptability of programmable automation. The rise of flexible automation has been fuelled by advancements in robotics, artificial intelligence (AI), and machine learning (ML), enabling systems to adjust dynamically with little to no downtime to meet varying production requirements. A prominent example of this in modern-day manufacturing is the consumer goods manufacturing industry, especially in the packaging and food processing segments. In the consumer goods sector, products can vary significantly in terms of packaging size, shape, and design, as well as in the food products being processed and packaged. Flexible automation systems in these industries are designed to handle various tasks with ease, adjusting to different product specifications on the fly. For instance, in food processing, flexible automation allows for quick and efficient changeover between different packaging types—such as bottles, cans, and boxes—for various products like beverages, snacks, and ready-to-eat meals. This is achieved through robotic systems, vision systems for quality inspection, and advanced software that can be programmed to accommodate different production needs. The technology enables the rapid adjustment of machinery to fit new packaging designs or product types, significantly reducing the time and cost of switching production lines. This flexibility is crucial for quickly meeting changing consumer demands, seasonal variations, and launching new products. Flexible automation supports the consumer goods industry's need for efficiency, product diversity, and high-speed production while maintaining the ability to rapidly adapt to market trends and consumer preferences, making it a vital technology in modern manufacturing processes.

Advantages

Flexible automation systems offer the highest degree of flexibility, allowing for the efficient production of various products with minimal changeover time. These systems can dynamically adjust production rates to meet fluctuating demand, supporting mass production and small-batch, customised manufacturing. The enhanced capability for product customisation and adaptation to market trends provides a competitive edge in rapidly evolving industries.

Disadvantages

However, the sophistication of flexible automation systems comes with high upfront costs, including investment in versatile equipment and advanced control systems. The complexity of programming and operation requires a workforce with specialised skills, potentially limiting the accessibility of flexible automation for smaller manufacturers. Additionally, integrating these advanced systems with existing manufacturing processes can pose significant challenges due to the substantial change in operation.

Control Systems and Process Variables

Flexible automation systems employ advanced computer controls, sensors, and artificial intelligence to seamlessly adapt to changing production needs. These systems can autonomously adjust process variables based on real-time feedback, such as machine speed, feed rates, and tool changes. Control systems in flexible automation include advanced robotics equipped with vision systems for quality inspection and adaptable material handling systems for efficient logistics. Integrating AI and ML enables these systems to learn from past operations, continually optimising performance and efficiency.

Conclusion

The evolution from fixed to flexible manufacturing automation underscores the industry's pursuit of greater efficiency, adaptability, and customisation. Each automation type offers unique benefits and poses distinct challenges, making them suitable for industrial applications and production requirements. Understanding the intricate balance between advantages, disadvantages, and the specific control systems and process variables of each automation type is crucial for optimising manufacturing processes and achieving strategic production goals. In-depth research and case studies further elucidating the practical applications, technological advancements, and future directions of manufacturing automation would enrich this analysis. Additionally, visual aids such as plant and block diagrams could significantly enhance the comprehension of these complex systems, offering valuable insights into the practical implementation of manufacturing automation technologies.

a) Flexible automation in flat-pack manufacturing

Flexible automation represents a significant evolution in manufacturing technology, offering adaptability and efficiency in production processes. For a company specialising in flat-packed furniture, flexible automation can dramatically enhance its operational efficiency, product customisation, and response to market demands.

The Nature of Flexible Automation

A key reason for using flexible automation is its ability to quickly adjust and change production operations without significant downtime or cost. This is achieved through programmable equipment and robots, advanced software, and modular production systems. Unlike fixed automation systems, designed for high-volume, low-variety production, flexible automation systems can efficiently handle many products and small batch sizes.

The Flat-Packed Furniture Industry: A Context for Flexible Automation

The flat-packed furniture industry is known for its variety of products, rapid product development cycles, and the growing demand for customisation and personalisation from consumers. Customers today expect high-quality, customisable furniture that can be delivered quickly and reasonably priced. Companies must have a production system capable of flexibility, speed, and precision to meet these demands.

Advantages of Flexible Automation in Flat-Packed Furniture Production

Product Variability and Customization: Flat-packed furniture ranges from simple tables and chairs to complex shelving units and wardrobes. Each product may come in multiple styles, colours, and sizes. Flexible automation allows manufacturers to switch product types and customise products according

to customer specifications without significant delays or retooling costs. This adaptability is crucial in meeting consumers' diverse and changing demands.

Efficiency and Scalability: Flexible automation systems can operate 24/7, reducing production times and increasing output. They are also scalable, meaning that as the company grows or demand fluctuates, the system can adjust without requiring a complete overhaul. This efficiency and scalability are particularly beneficial for flat-packed furniture companies that experience seasonal demand spikes or rapid growth.

Quality Control: Automated systems provide consistent and precise quality control checks throughout production. This ensures that every piece of flat-packed furniture meets the company's quality standards, reducing waste and the cost associated with returns or repairs. High-quality products also enhance customer satisfaction and loyalty.

Inventory Management and Just-In-Time Manufacturing: Flexible automation facilitates just-in-time manufacturing practices, minimising inventory costs and reducing warehouse space requirements. By producing furniture close to the time of order, companies can respond more quickly to orders and reduce the risk of overproduction or stock obsolescence.

Sustainability: Automation can lead to more sustainable production processes by optimising material use and reducing waste. Automated systems can be programmed to maximise material efficiency, for example, by optimising cutting patterns to minimise scrap. This reduces costs and supports environmental sustainability, an increasingly important consideration for consumers and businesses.

Why Flexible Automation is Most Appropriate for the Flat-Packed Furniture Industry

The flat-packed furniture industry's unique characteristics make flexible automation the most suitable approach. The need for product diversity, customisation, efficiency, and sustainability aligns perfectly with flexible automation's strengths. As the industry continues to evolve, with trends toward more personalised furniture and environmentally friendly materials, the ability of flexible automation systems to adapt and scale will become even more critical.

Moreover, the competitive landscape of the flat-packed furniture market requires companies to continuously innovate and improve their operational efficiencies to maintain profitability and market share. Flexible automation provides the tools necessary to achieve these objectives, enabling companies to stay ahead of market trends and meet consumers' changing needs.

In conclusion, adopting flexible automation in the flat-packed furniture industry offers a pathway to enhanced operational efficiency, product customisation, and market responsiveness. Its ability to adapt to a wide range of products, manage small batch sizes efficiently, and maintain high-quality standards makes it the most appropriate type of automation for this sector. As companies strive to meet the growing demands for customisable, high-quality, and sustainable furniture, flexible automation will undoubtedly play a pivotal role in shaping the industry's future.

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