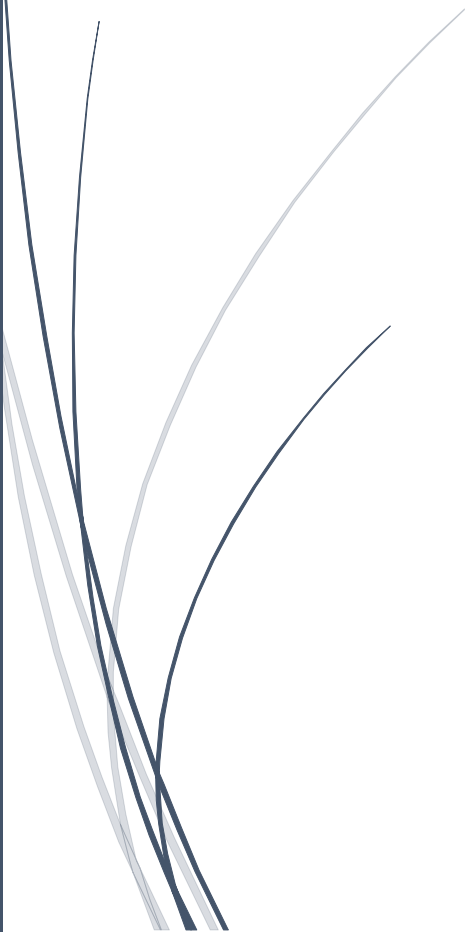


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3/20/2023

ACMA5001 Control & Automation

Development and Application of
Manufacturing Automation

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Joseph McBride

UNIVERSITY OF WALES TRINITY SAINT DAVID

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Introduction

Over the last few decades automation has become much more prominent in the manufacturing industry. The technology now available allows for the automation of processes that would have previously required human intervention to complete tasks. This report will look at the three main types of manufacturing automation. These include fixed, programmable, and flexible automation. More specifically this report will investigate the history, origin industry, advantages, and disadvantages of the three automation types mentioned above.

Also analysed in this report will be the systems implemented to control the automation processes and the process variables associated with the automation manufacturing processes discussed. Automation is now utilised throughout multiple manufacturing industries therefore a variety of examples will be included.

Fixed Automation

The first type of automation covered is fixed automation. This is where the process is predetermined to manufacture a certain product. A fixed automation systems configuration would be limited therefore the integration of an additional product would entail a high degree of complexity. Sometimes fixed automation may be referred to as 'hard' automation. Often fixed automation systems are utilised throughout the manufacturing industry to automate the assembly of a product. The assembly process of the product being manufactured via a fixed automation system is usually a consecutive operation. Fixed automation examples include "automated assembly machines, chemical manufacturing processes, material handling conveyor systems and paint and coating automation processes" (Aurora, 2023).



Figure 1 - Fixed Automation Example (Encompass Solutions, 2023)

Advantages & Disadvantages

There are various advantages and disadvantages associated with fixed automation. One of the advantages fixed automation is that high production volumes can be achieved since the system is designed specifically to manufacture a particular product. This also aids in achieving a "consistent quality in production" (Control Freaks, 2020). Fixed automation systems also help to reduce the manufacturing costs of products due to the systems being designed with minimal human interaction meaning production lines can run continuously.

This type of automation can also have some downsides. For example, there is often an elevated initial setup cost due to the specialist equipment required to build the automated system. Another disadvantage of fixed automation is that it is nonflexible meaning if there was a scenario where another product needed to be manufactured on the system it would be difficult to integrate and may require a high degree of changes to do so. This can often be an issue if there are multiple variations of the same product that are introduced after the fixed automation system has been implemented.

History

Fixed automation can be considered as the first type of automation to be seen in history. When Ford Motor Company introduced their automotive assembly line in 1913 this was considered "pioneering types of automation in manufacturing" (Porter, 2021). With the advances of technology over the following decades fixed automation systems became more advanced. Control systems were implemented in the 1930s which allowed fixed automation systems to respond to the deviations in

the manufacturing process. An example of this would be temperature controllers which would adjust the system accordingly based on the feedback it received. After World War Two Japan began rebuilding its industrial economy. This created the opportunity for Japan to become one of the worlds leading countries in terms of automation technology. A variety of car manufacturers including Nissan, Mazda and Honda have employed automation since this time and continue to produce high quality automobiles even to this day.



Figure 2 - Japanese Automotive Industry (Cross Currents, 2023)

Plant or Block Diagram

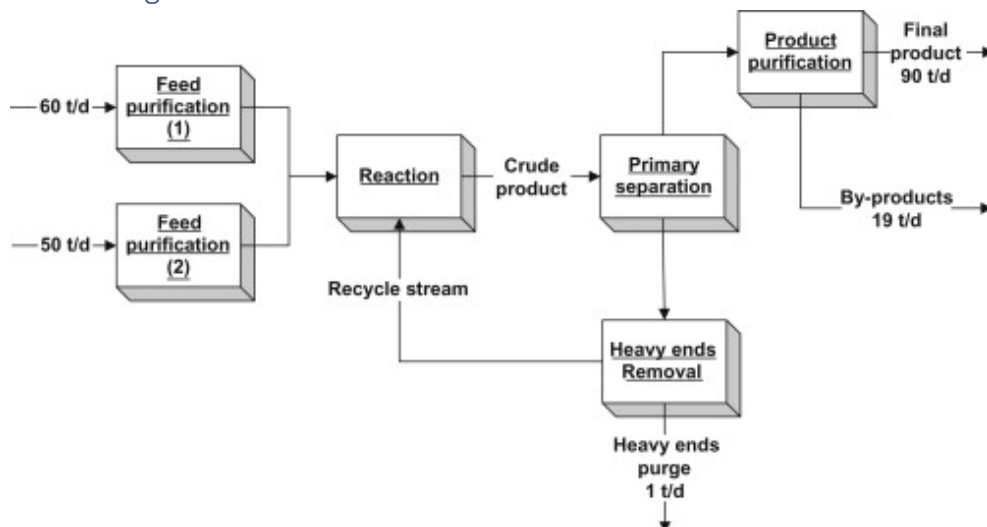


Figure 3 - Fixed Automation Block Diagram (Science Direct, 2023)

Figure 3 shows a block diagram example of a fixed automation system. The manufacturing process of the system can be considered linear and the final product output from the process is fixed and would not be nonflexible. To be able to output variations of the final product modifications would need to be made to the system to achieve this. For this reason, it can be considered as a fixed automation system.

Programmable Automation

Another type of automation is programmable automation. This type of automation allows for versatile manufacturing process to produce a wide range of products. Programmable automation systems can be operated via a series of instructions which are then uploaded to execute the manufacturing process. If the manufacturing process, then needs to be adjusted the automation system instructions can be reprogrammed. These types of systems are often used in manufacturing process where the product output varies often. This type of automation systems implements several control systems including “CNC (Computer Numerical Controlled) machine tools, industrial robotic applications and programmable logic controllers (PLC)” (Engineered Automation of Maine Inc, 2020). Programmable automation is often used when production volumes are low to medium compared to high production volumes. Examples of programmable automation include automatically loaded CNC machines and package handling systems.



Figure 4 - Programmable Automation Example (Mills CNC, 2023)

Advantages and Disadvantages

Multiple advantages and disadvantages can be associated with programmable automation. One of the advantages being that it allows for flexible product manufacture which is essential when there are several variations of similar products or products that have a comparable manufacturing process. The versatility of programmable automation systems is also beneficial when “batch production is required” (Control Freaks, 2020).

There are also disadvantages associated with programmable automation. A downside would be the high equipment cost due to its programmable nature. It is also difficult to achieve high production volumes with programmable automation compared to a fixed automation system. This low production volume is another disadvantage. Even though programmable automation systems are flexible in nature it can often require a high degree of effort to implement a change in the system. It is also likely that a technical knowledge would be required to make the program change which means it is not accessible to all personnel.

History

Programmable automation has been around for a few decades in the form of PLCs. First introduced in the automotive industry in the 1960s, PLCs aimed to replace electrical contacts such as relays with a programmable solution. Allen Bradley was one of the first manufacturers of PLCs and the products produced are still used in the modern day. PLCs have developed significantly over the years and are

now more advanced than ever. In the 1990s HMIs (Human Machine Interfaces) were developed so that the PLC could be interacted with through a more basic format which in turn allowed engineers to fault find systems with ease. One of the main reasons the PLC is so heavily used on programmable automation systems is that the ladder logic programming language can be picked up easily by engineers and technicians with varying skillsets.



Figure 5 - PLC (Programmable Logic Controller) (Toshiba, 2023)

Plant or Block Diagram



Figure 6 - Programmable Automation Plant Diagram (Agile Robotic Systems, 2023)

Figure 6 shows the plant layout of a programmable automation system. This consists of a CNC machine incorporated into a robotics cell. The CNC in this scenario can be programmed to manufacture variations of machinable parts. The robotic within this system can then be programmed to unload the parts from the CNC machine. This automation system would not be a suitable solution for mass production parts however, it would be suited for low to medium volume manufacturing processes.

Flexible Automation

The final type of automation is flexible automation, this is often referred to as soft automation. Flexible automation can be considered as a combination of fixed and programmable automation. The reason for this being that medium to high production volumes can be achieved without the reprogramming aspect. This type of automation can manufacture multiple variations of products without them being split into batches. Flexible automation “can improve efficiency by evolving with your process and demand” (Cross Company, 2022). Industrial robots are usually implemented in flexible automation control systems due to their ability to perform a range of different tasks once initially programmed. Flexible automation can be found throughout several different manufacturing industries including automotive, logistics and packaging industries. Examples of flexible automation include automotive assembly lines and plastic manufacturing systems.



Figure 7 - Flexible Automation Example (Geomiq, 2023)

Advantages and Disadvantages

One of the advantages associated with flexible automation is that they often reduce manufacturing costs to the company once it has been implemented and help to increase production efficiency. Another benefit of flexible automation systems is that they can thwart defective products from being manufactured and reaching customers. The reason for this being that there is little to no human intervention during the manufacturing process which is usually the cause for defective products. There are often vision checks in place on flexible automation systems which control the products being manufactured. These vision systems also heavily reduce the number of defective units reaching customers.

The main disadvantage linked with flexible automation is the initial setup cost. Large investment is usually required by companies looking to implement flexible automation due to the high cost of the specialist equipment and to train or obtain extremely skilled employees who can design and introduce flexible automation process into the manufacturing environment. Employees who work with flexible automation usually require a multitude of skills including PLC programming, electrical understanding, mechanical aptitude, and a robotics knowledge. To employ persons with the skillset previously mentioned it would require a lucrative salary to attract them to the business. Flexible automation systems can also have large maintenance costs due to the variety of equipment that they are comprised of however, this maintenance cost is usually cancelled out by the return on investment that this type of automation system brings.

History

Flexible automation systems have been around from as early as the mid-1960s. The flexible automation system in question “was developed by the Sunstrand Corporation in 1965” (Stecke & Parker, 2000). It was constructed of eight numerical controlled machine tools which were then connected via a roller conveyor. Even though the opportunity from flexible automation was low it was still considered to be one of the first flexible automation systems due to the ability to select different part types to be manufactured on the system.

Historically flexible automation has been used throughout the automotive industry with Ford Motor Company being one of the first vehicle manufacturers to introduce this automation type. Automation was a term introduced by “D.S. Harder, an engineering manager at the Ford Motor Company at the time” (Groover, 2023). Modern day flexible automation systems often utilise AI (Artificial Intelligence) to create more intelligent automation systems with machine learning capabilities. These more advanced flexible systems are seen throughout many manufacturing industries already.

Plant or Block Diagram

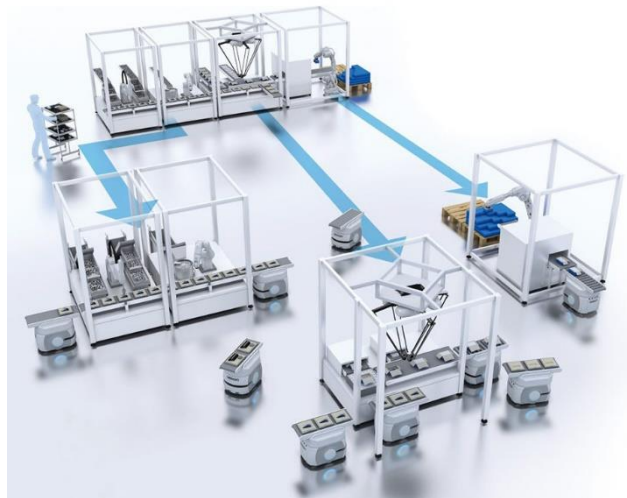


Figure 8 - Flexible Automation Plant Diagram (Machinery World, 2023)

Figure 8 shows the plant diagram for a flexible automation system which consist of a few different robotic cells along with AGVs (Autonomous Guided Vehicles) to transfer the product being manufactured between the various stations. The equipment implemented within this flexible automation system is highly advanced and would require multi skilled engineers and technicians to build and commission the system. All the equipment and components used within this system could be configured in such a way to achieve a variety of products as the final output. Once implemented it would also be able to achieve high production volumes with little human intervention.

Flexible Automation in Flat-Packed Furniture Manufacture

Flat-packed furniture can be manufactured via a few different automation processes including fixed, programmable, and flexible. One of the main ways in which flat-packed furniture is currently manufactured is by using programmable automation systems such as CNC machines. There may then be other manual operations within the manufacturing process such as finishing and packaging before the product reaches the customer.



Figure 9 - Flat-Packed Furniture (Trend Hunter, 2023)

A large flat-pack furniture company such as IKEA may employ a flexible automation manufacturing process instead of the more programmable solution mentioned above. The reason being that they would need to achieve high production volumes for several different product types which would all have several variations. This type of flexible automation system for flat-pack furniture may be comprised of industrial robots, conveyors, CNC machines and PLCs. The robotic aspect in this system may be used for part handling and sorting and would have a few tooling attachments so that it is compatible with the variety of product types. Conveyors could then transfer parts to the different assembly stations however, in more modern solutions AGVs or AMRs (Autonomous Mobile Robots) maybe used in place of conveyors. CNCs with a variety of tooling attachments and an automatic loading process could be used for machining the flat-pack furniture to the required dimensions and the PLC in the process would act as an overall controller for the whole system.

Often in the type of flexible automation system described above vision systems will be used within the control system to inspect parts and prevent defective products reaching the customer. Many of the modern-day vision systems, from manufacturers such as Cognex, utilise AI (Artificial Intelligence) and machine learning to help distinguish between the varying part types. This is extremely useful in a flexible automation system where intelligent equipment is required to create a robust process. Overall, a flexible automation system is highly suitable for the manufacture of flat-packed furniture in large production volumes.

Summary

Since the introduction of automation within the manufacturing industry the range of advancements have been made. Historically fixed automation systems were more common before moving onto more programmable solutions and finally with the help of modern-day technology automations systems have become more flexible than ever. The equipment used within automation systems continues to advance today with the integration of AI making manufacturing processes more intelligent than ever.

Automation has helped to create multiple career opportunities within the manufacturing industry with many engineers and technicians now specialising in the field. Many companies now design products with the aim of manufacturing the parts with an automation system. The reason being that it presents the opportunity for companies to create highly capable manufacturing process which will then enable them to react to customer orders promptly. This means companies can respond to an increase in customer orders without having to increase head count to achieve this which is a much more sustainable solution.

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