INDO AMERICAN JOURNAL OF PHARMACEUTICAL RESEARCH

ROBOTICS IN PHARMACEUTICAL INDUSTRY

Kundap S., Karpe M., Kadam V.

Bharati Vidyapeeth's College of Pharmacy, Belapur CBD, Navi Mumbai, 400614, India.

ARTICLE INFO

Article history
Received 01/10/2021
Available online
31/10/2021

Keywords
Robotics,
Robot Statistics,
Pharmaceutical Industry,
Manufacturing,
Nano Robots.

ABSTRACT

This article intends to provide information on pharmaceutical robots used in industry, as well as to gather and analyse data from previous years relating to the deployment of industrial robots in the market and their impact on worker employment or jobs. Cartesian, SCARA, and articulated robots are the three most prevalent types of industrial robots. These robots can be used in sterile production, laboratories, packaging, 3D printing, and a variety of other pharmaceutical applications. Only a few micro and nanoscale robots are available for drug delivery. As a result, the use of robots has increased. A market analysis of robots as well as a research of the robotic performance to price ratio was conducted. Based on the research, Asia is the world's largest industrial robot market, with an annual installation rate of 13% from 2014 to 2019. According to the performance to price ratio, quality adjusted robot prices were about one-fifth of what they were in 1990 by 2005. This accounted for 15% of overall productivity growth. According to the study, the number of installations is growing year after year, and many companies are contemplating pharmaceutical robots because of their numerous pharmaceutical applications, benefits, flexibility, and capacity to securely collaborate with people. It is expected that in the near future, robotics will play an important role in the pharmaceutical industry.

Corresponding author
Kundap S.
Bharati Vidyapeeth's College of Pharmacy,
8,YMCA Marg, Sector 3A, Belapur CBD,
Navi Mumbai, Maharashtra 400614, India.
svkundap@gmail.com
9833390847

*Please cite this article in press as **Kundap S.** et al. Robotics in Pharmaceutical Industry. Indo American Journal of Pharmaceutical Research.2021:11(10).*

INTRODUCTION

Filling, inspection, packaging, laboratories, and the production of tailored medicine all benefit from robots. Pharmaceutical manufacturing is increasingly relying on automation, including automated inspection, and packing. Some robots are remote controlled, some are semi-autonomous while some are fully automatic robots. To underline the difference between robots and other machines, the term autonomy has been used which refers to the ability to interpret its actions and the environment and adjust the actions to achieve a certain goal. [1,2]

This article gives a broad overview of robotics in the pharmaceutical industry, focusing on the different types, applications, benefits, and overall installation and price data of industrial robots. As advanced robots and automation have the potential to transform the manufacturing industry, especially for small and medium-sized businesses. Adopting these new technologies has become an urgent necessity in order to provide high-quality products while also supporting research, development, and production. Because, a lack of knowledge about these new upcoming technologies can be a barrier to innovation and development in the pharmaceutical industry. As a result, efforts have been made to disseminate necessary information and encourage the use of robotics technology.

Robotics:

Robotics is a technical branch concerned with the design and development of robots. It is a widely spreading and evolving branch in technology as the use of robotics is increasing day by day. It drives the development of robots for its use in various areas such as hospitals, pharmacies, pharmaceutical industries, factories, etc. [2,3]

Robots:

A robot is a machine that can be programmed to perform specific tasks. A robot can be autonomous or non-autonomous, intelligent, or non-intelligent. Autonomous robots can operate and complete tasks without human interaction and make their own decisions. [1,3]

Isaac Aminov's: Three laws of robotics

Isaac Aminov was a science-fiction author who wrote the 'Three Laws of Robotics,' with the fourth law, known as the 'Zeroth Law,' added later. They are as follows:

I. A robot must not injure a human being.
II. Except where such directives clash with the First Law, a robot shall obey directions provided to it by humans.
III. If it does not clash with the First or Second Laws, a robot must defend its own existence.
IV. A robot must not harm humanity. [2]

Types of robots:

In pharmaceutical manufacturing, there are three categories of industrial robots:

Cartesian:

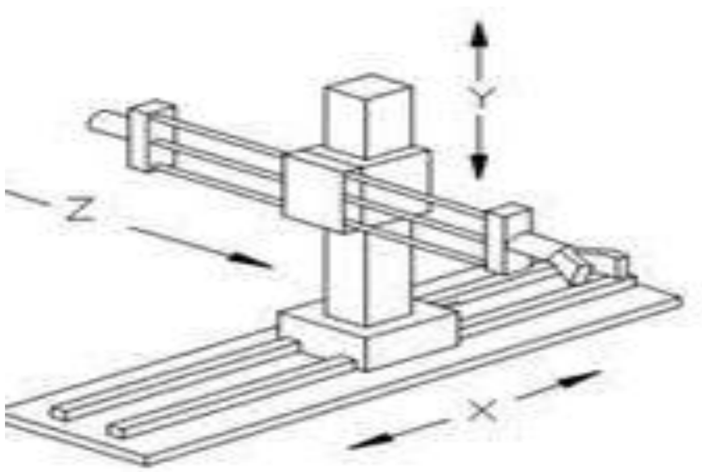

Figure 1: Cartesian robot showing x, y and z axes.

Cartesian robots include two linear slides which are placed at 90-degree angles to each other which are then accompanied with a motorized unit that moves horizontally along the slides in the z axis, which moves up and down in the vertical plane. The quill holds the robots end-effector, such as gripper. A fourth axis (t/theta), it allows the quill to rotate in the horizontal plane. The main advantage of Cartesian robots is that they are less expensive, although their restricted range of motion has a limiting effect on their range. They're frequently used in automated systems or devices that specialise in a certain task, such as assay testing. [4].

Selective Compliance Articulated Robot Arm (SCARA) robots:

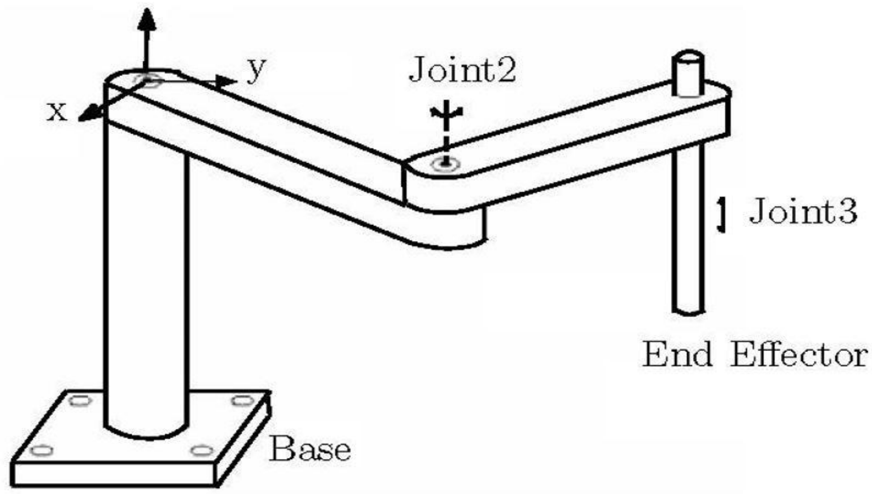

Figure 2: SCARA robot.

SCARA stands for selective compliance articulated robot arm. This refers to the arm segments, or links, of a SCARA being able to freely move but only in one geometrical plane. Most SCARAs has four axes, but three axis and five axis SCARA robots are also found. A SCARA has first two links that swivel left and right in the horizontal plane around the first two axes. In SCARA robot quill is the third link, which moves up and down along the third axis in the vertical plane. The quill rotates horizontally in the fourth axis but is unable to tilt at a vertical angle. Some SCARAs have a metal shaft that is a hollow air balance cylinder. In SCARAs, the purpose of this cylinder is to counteract the weight present at the end effector and payload, reducing settling time that means the time in which robot must wait for some time after it moves to a given point before carrying out any of its next movement. The advantage is seen due to the presence of fixed swing arm design, the limitations in SCARA robots is when it comes to tasks that require moving or working around. SCARA robots have small footprints and are lightweight, thus they make them ideal for applications in crowded spaces. SCARA robots are capable of very fast cycle times. [2,4]**.**

Articulated robots

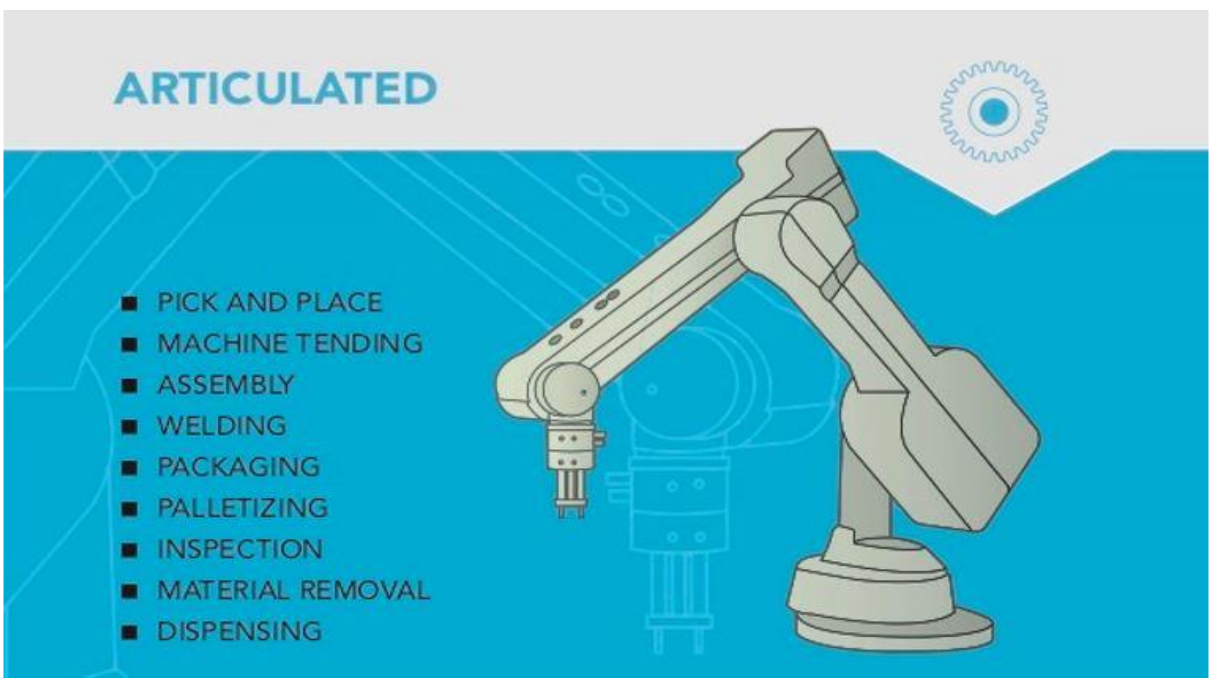

Figure 3: Articulated robot.

Articulated robots provide increased freedom of movement as they have both vertical and horizontal joints. They also have more joints than SCARAs. For articulated robot the work envelope is spherical and for cartesian robot and SCARA robot the work envelope is cube shape and cylindrical shape respectively. Articulated robots show movement with greater flexibility and can perform tasks similar to the tasks performed by human hand or human arm. The most common articulate robot has six axes. The first link rotates in a plane that is horizontal like a SCARA while the other two links (second) rotate in a plane that is verticle. Six axis articulated robots performs movements same as the human arm (forearm and wrist). This is because of the presence of a vertically rotating wrist joint and also a vertically rotating forearm which allows increased movements. The human like forearm and wrist joint of six axis articulated robots allows them to pick up an any material or object or packaged boxes off the horizontal plane irrespective of its orientation. It not only allows picking up of the object but also placing the object at any required angle of approach. Articulated robots can perform many other tasks too. [4]

Things to consider while selecting a robot

For the application of robot in a particular clean room, choosing a correct robot depending on its classification and strictness of the cleanroom environment is important. Certification of robot occurs according to the number of particles they generate when they are in motion and according to this their use in different industries and cleanrooms is decided. Robots have a tendency of shedding particles from gasses from hoses, belts, and dust particles from the movement of the robotic arms or the end effectors. In pharmaceutical manufacturing industries, manufacturers should ensure that the robot is certified according to the cleanroom levels for use in pharmaceutical, biotechnology and medical industries. [5]

Status of robotics in pharmaceutical industry

Various tasks in pharmaceutical industries, laboratories are performed by robots. These robots work in dangerous or hazardous environments in vicinity of toxic chemotherapy compounds, biological hazards and in the risk of radioactive contaminants.

Robotics are used in packaging too, to assemble and package a number of implants and medical devices. Robotics are also used in making prescriptions for mail order pharmacies and hospitals.

Robots are also used for picking and placing of objects in case if the objects are flexible, quick and slim. Customized orders are also placed by robots and tasks like assembling blood sugar kits are also performed by robots.

Robotics are beneficial in packaging, handling of test tubes and for drug discovery jobs. Medication errors occurring during packaging and dispensing in hospitals can be eliminated by use of PillPick which is a pharmacy automated system that can be used to increase patient safety.

Robotics are also being used in laboratories to provide efficient working. For example: SciGene which is a robot used for the preparation of Deoxyribonucleic acid (DNA) samples and Varian's auto-sampler is a robot used in picking up of test tubes and loading them in an Nuclear Magnetic Resosnance (NMR) magnet.

Many pharmaceutical industries are looking for improved sustainability in their operations and for achieving this many manufacturers had to conserve energy by reducing waste and pollution. Robots can work out on these goals as the gearboxes, motor and drives that run them have proved to be 95% energy efficient. [6]

Robot market analysis and study of robotic performance to price ratio

Because of the huge number of local pharmaceutical businesses and increased adoption of robot strategy, Asia Pacific is the fastest expanding area in the global pharmaceutical robotics market. China, Japan, and South Korea are the primary countries in the Asia-Pacific area with a global centre of vital pharmaceutical firms, as well as the presence of leading robotics companies. According to the International Federation of Robotics, over 2,83,000 industrial robots were deployed in Asia Pacific in 2018, with around 2,85,000 units installed in 2019. A manipulating industrial robot, this term is defined by the International Federation of Robotics (IFR) as "a reprogrammable, an automatically controlled, multipurpose manipulator programmable in three or more axes, which may be either mobile for use or fixed in place in industrial automation applications, as defined by ISO 8373: An automatically controlled, reprogrammable, multipurpose manipulator that can be programmed in not less than three or more axes and it can not only be fixed but also mobile for use in industrial automation applications."

The cost of industrial robots in six major industrialised economies fell by about half between 1990 and 2005, according to statistics from the IFR (2006). When quality improvements are factored in, the price drop is considerably greater: quality-adjusted robot prices were around one-fifth of what they were in 1990 by 2005. [7,8] Kent Massey believes that, based on these trends, the performance-to-price ratio will double every 4 to 10 years, depending on the assumptions utilised (personal communication, June 13, 2014). The cost of integration is also starting to decrease. Industry experts estimate that the entire cost of robotic systems (original expenses plus integration costs) is 3 to 4 times the initial cost of each robot; however, this ratio is shifting. Auxiliary products and services required to get the robot up and running are included in the integration costs. [9,10] According to IFR (2013), supplementary products and services have a 3X multiplier, which is consistent with industry experts' beliefs. [11]

As robot prices fell rapidly, more robots were used per human hour of work in a variety of industries. [8] It appears that robots lower output prices, which benefits consumers and downstream producers. It appears to increase total factor productivity (TFP) and average salaries as well. [8] It was discovered that growing deployment of industrial robots is associated with increases in worker productivity using a panel of industries in seventeen nations from 1993 to 2007. We find that greater use of robots contributes significantly to productivity growth, with 0.36 percentage points accounting for 15% of overall productivity growth using conservative assumptions. [8] Even in the industrialised economies we studied, industrial robots accounted for just about 2.25 percent of the capital stock in robot-using businesses in 2007, and their utilisation was rather limited.

There is every reason to think that robots will continue to boost labour productivity if their quality-adjusted prices continue to fall at a rate equal to that seen in previous decades, and as new uses are created. [8] Increased robot use added 0.36 percentage points to annual labour productivity increases, while also improving total factor productivity and cutting output prices, according to the research. According to the estimations, robots did not considerably diminish total employment, but they did reduce the employment percentage of low-skilled workers. [8]

Large-firm robotic maturity: An additional categorical variable was established to add more information to the large-firm robotic profile. The model finds this variable to be useful in explaining the robotic maturity of this type of company since large enterprises have a higher percentage of robotisation and have been using these technologies for a longer period of time. This variable, in the form of a percentile, captures the company's maturity in terms of robotics adoption based on the amount of time it has spent employing this technology during the observation period. The variable can take five different values ranging from 0 to 4:

- 0: The business has never been robotic.
- Value 1: The company has been robotic up to 25% of the years in the sample.
- Value 2: The company has been robotic up to 50% of the years in the sample.
- Value 3: The company has been robotic up to 75% of the years in the sample.
- Value 4: The company has been robotic more than 75% of the years in the sample. [12]

Robot installation statistics and Summary of world robotics in 2020 industrial robots

According to the installation statistics from last two years, Asia is the world's largest industrial robot market. Installations fell by 13% in 2019 after six years of record highs. There were 245,158 units installed, down from a high of 283,080 in 2018. In 2019, Asia was home to two out of every three new robots (66 percent). From 2014 to 2019, yearly robot installations increased by an average of 13% every year. The scenario is similar in Asia's three major markets: the Republic of Korea (27,873 units; -26%), China (140,492 units; -9%) and Japan (49,908 units; -10%). The number of robots deployed in Europe, the second largest market, fell by 5% to 71,932 units, down from a high of 75,560 units in 2018. This, like Asia, signalled the conclusion of a six-year period of expansion. From 2014 through 2019, the annual average growth rate was 10%. [13] Five countries account for 73% of global robot deployments. China, Japan, the United States, the Republic of Korea, and Germany are the five biggest markets for industrial robots. These countries account for 73% of all robot installations worldwide. [13] According to the new World Robotics 2020 Industrial Robots study, there are now 2.7 million industrial robots in workplaces around the world, a 12 percent increase. Sales of new robots are still strong, with 373,000 units sold worldwide in 2019. This is 12% less than in 2018, however it is still the third greatest sales volume ever. [14] The global economic repercussions of the coronavirus pandemic have yet to be properly analysed. The present sales slowdown of 12% in 2020 reflects the challenging conditions that the two major customer industries, automotive and electrical/electronics, are facing. The automation initiatives and demand for robots are projected to take a few months to materialise. The year 2021 is shaping up to be a rebound year but getting back to pre-crisis levels may take until 2022 or 2023. [14]

Application of robots in pharmaceutical industry

Pharmaceutical industry consists of various sectors. In such industries, cost, speed, quality, and flexibility are the four types of production factors that are typically addressed in any sector. Quality is a statutory requirement in the pharmaceutical sector, while the main drivers have traditionally been lower upfront costs and increased speed. Machine, system, and facility flexibility will become more crucial in the future, as uncertainty and complexity in products, volumes, and markets will necessitate making quick adjustments while retaining excellent manufacturing flexibility. Continuous manufacturing is gaining traction at the system level, with robotics/automation being applied to oral medicinal products and alternate drying technologies. [14]

Robotics in Sterile Manufacturing

The ability to handle sterilised components and ingredients without recontamination is defined as robust aseptic processing, which necessitates active process risk management. The most effective way to limit the risk of contamination is to reduce or eliminate the possibility of it happening in the first place, and to make the process seamless in a continuous workflow. During aseptic processing, a rigorous sterility assurance strategy focused on contamination control should restrict or eliminate human interaction while making the process faster and more consistent. Robotics are used to overcome the difficulty of removing the human element from aseptic processing. Another benefit is that particle contamination from traditional prescription product fill finish manufacturing is avoided. A clean room organised into modular process blocks can be envisioned as one form of robotic aseptic processing. The isolator technology can provide Grade A air with the proper pressure cascade to support process design and regulatory needs. Under the continuous manufacturing paradigm, this example also highlights the ability to customise and design a flexible, agile end-to-end process that can de-nest various ready-to-use container closures (e.g., vials, syringes, cartridges) as well as assist with different processing stages (e.g., lyophilization). The concept of scaling out a clinical batch to many robotic process lines employing robotic, modular technology allows for faster technology transfer for a worldwide launch plan. [15,16-21]

Research and Development (R&D)

Robots are already playing an increasingly important role in the creation of novel pharmaceuticals. Millions of chemicals are evaluated in high throughput screening (H.T.S.) to see which ones could become new medications. The employment of robotics to test these millions of chemicals is required. Robotics, like any other procedure in which a robot substitutes a person performing a repetitive duty, can dramatically speed up this process. [22].

For example, In Southern States University, robotic arms are widely used in high-throughput screening operations. High Throughput Screening (HTS) consists of a plate called a microplate: it is a small container which is disposable, and these microplates are made up of plastic, that features a grid of small, open wells acting as miniature test tubes for carrying out the required task. The number of wells differs from microplates to microplates such as modern HTS microplates generally have wells starting from 384, 1,536, 3,456 to 9,600 wells. Using robotics, sensitive detectors, liquid handling devices, and software for processing of data and system control, HTS allows millions of genetic, chemical, or pharmacological tests to be conducted very rapidly. Through this process one can rapidly identify active compounds, antibodies or genes which modulate a particular biomolecular pathway, and these experiments provide starting points for drug design and for understanding the role and interaction of a chosen or particular biochemical process. [23-26]

Control Systems

Onboard controllers on most robot's interface with other machines' programmable logic controllers (PLCs) or networked personal computers (PCs). Robot controller is a VERSA-Module Euro card (VME) bus controller for industrial applications that connects to PCs for networking and graphical user interfaces.

Laboratory Robotics

Instead of monotonous chores that lead to weariness and blunders, this new technology allows human abilities to be focused on sample selection and submission, as well as scrutiny of the generated data. Of course, better data and lower costs are the anticipated outcomes of this automation. New laboratory robotics-based experimental processes are eliminating human tedium and error in transporting and washing. This comprises radioactive, fluorescent, and luminescent analytical experiments. Pharmaceutical development is rapidly using laboratory robotics to help satisfy the needs of boosting productivity, shortening drug development time, and lowering costs. Cartesian (three mutually perpendicular axes), cylindrical (parallel action arm pivoted around a central point), and anthropomorphic are three of the most prevalent geometries for laboratory robots (multijointed, human-like configuration). [22,24-26]

Sterilization and Clean Rooms

Robotics can be modified to work in sterile conditions. The features of clean room robots prevent the sterile environment from infection. Low flake coatings on the robotic arm, stainless steel fasteners, specific seal materials, and enclosed cables are among these qualities. Robots in clean rooms save money by automating tasks such as inspection, picking and placement, and loading and unloading process tools. The following are some of the advantages of using a robot in a clean room:

1. Robots help to reduce contamination-related scrap.
2. Robots cut down on the need for clean room consumables like bunny suits.
3. Robots reduce scrap by reducing the number of pieces that are mishandled or dropped.
4. Clean room protocol enforcement and training expenditures are kept to a minimum.
5. Robots save money on clean room area by removing lanes and access points that are traditionally required for human clean room workers.

Miniature surroundings can also be created for robots. This allows for a more relaxed level of hygiene throughout the rest of the facility. [27]

Packaging Operations:

Packaging activities, like other pharmaceutical operations, benefit from automation's speed and consistency. Robotics, in particular, offers versatility and precision. Robotics can also outperform specialist machines in some packaging applications, such as carton loading. Pharmaceutical packaging machines are frequently designed to accommodate specific product configurations, such as vials.

Advantages over Traditional Automatic Packaging Machines

Unlike packaging machines, which stop automatically if too much product accumulates at the discharge, robotic loaders and unloaders meet or exceed the in feed and discharge rates required by packaging machines. This capability enables the robot to maintain full production capacity throughout the packaging process.

Advantages of Robotic Automation of Packaging

1. Speed - Robots work quickly and efficiently, without wasting movement or time. Robots can change productivity by increasing throughput without taking breaks or pauses.
2. Versatility - Packaging applications can vary. Robots are simple to reprogram. Changes in end-of-arm tooling (EOAT) development and vision technology have expanded packaging robots' application-specific capabilities.

Flexible Feeding

Robots are also superior to hard automation at flexible feeding, a task that requires handling multiple types of products or packages with varying orientations. High-speed, automated bowl feeders that vibrate parts and feed them to fillers, labellers, or product-transfer mechanisms have traditionally been used on packaging lines. Bowl feeders, on the other hand, cannot always handle a variety of products at the same time, and their vibration can damage fragile parts. [23,27]

Vision Systems

A vision system can help determine the accuracy of text and graphics in pharmaceutical and medical packaging. The main advantage of incorporating a robot into the vision system is increased speed. It inspects insert in under two minutes. The same inspection performed by one operator and checked by another could take 30 minutes to an hour.

Grinding Applications

Manual grinding is a difficult, dirty, and noisy job. Grinding metal dust is hazardous to a worker's eyes and lungs. Grinding robots eliminate the need for manufacturing workers to work in hazardous conditions. [23,27]

Sterile Syringe Filling

Stericlean, a three-way collaboration between robotics specialist Staubli, factory automation firm, and pharmaceutical manufacturer Sanofi-Aventis, was introduced at Interphex as the market's only robot arm that can be used in barrier isolation systems. Stericlean has significantly increased our productivity by replacing manual processes.

Biopharma and Diagnostic Applications

It offers standardised solutions with high throughput and reproducible, accurate results in fields such as genomics, cells and proton sciences, and forensics. It provides pharmaceutical laboratories with automated solutions for cell culture, nucleic acid extraction, normalisation, genotyping, protein purification and analysis, hit picking, Absorption Distribution Metabolism and Excretion (ADME) screening, Polymerase Chain Reaction (PCR) applications, and protein crystallography. [22,16-21]

Other use of robots:

3D Printing

In the industrial sector, 3D printing has been actively used for rapid prototyping and printing intricate contact parts. The technology is slowly making its way into the pharmaceutical industry. 3D-printed pill, and pharmaceutical medication items and devices have been the subject of intensive study in business and academia. [15]

Rapid Prototyping Using 3D Printing

3D printing can also have an impact on lab scale activities, packaging innovation, device ideation, and bringing numerous ideas to fruition in previously unheard-of turnaround times. In a laboratory, replacing a broken part, designing parts to facilitate experiments, and reducing redundant activities can all have a significant impact on performance and results. For example, the use of parenteral drug products is gradually increasing as a result of the emphasis on biologics and device development, both of which can be greatly influenced by 3D printing. The ability to quickly translate ideas from design to physical part allows for novel changes to be implemented and user experience to be efficiently gauged. Similarly, packaging options that can help reduce costs and simplify the use of complex devices can be beneficial to patients. As a result, the ability of 3D printing to impact multiple areas of drug product development makes it a future mainstay. [15]

Gastrointestinal video capsule magnetic robotic manoeuvring

The use of ingestible video capsules for gastrointestinal explorations of the digestive tube began in clinical practise a decade ago, followed by an ever-improving diffusion that is still ongoing today. Given Imaging Ltd, Yoqneam, Israel, produces the most common commercial product, the capsule M2A. This pill-shaped device integrates image capture, wireless data transmission, and power supply functions in a small package (26 11 mm, 3.23 g) as a remarkable result of major advances in microelectronics. It is swallowed by the patient and travels through the digestive tube until it is naturally expelled from the body. The video capsule illuminates the gastrointestinal tube wall and automatically takes pictures during its operation, which typically lasts 8 hours. Data collected is wirelessly transmitted to a wearable external recorder. At the end of the procedure, data from the recorder are downloaded into a workstation, where the video frame sequence is reconstructed for offline analysis by the physician. Video capsule endoscopy is rapidly spreading in gastroenterology because it allows for non-invasive and comfortable optical examinations of the digestive tube. [28]

Micro robots for drug delivery in eye

The concept of using microrobots for drug delivery in the eye was first conceived nearly 20 years ago, when feasibility studies on magnetic manipulation and control of microsystems in body fluids were conducted. These implants were designed to be injected through the durable pars plana region into the vitreous cavity using a 23-gauge needle and topical anaesthesia, and then guided toward the retina using electromagnetic fields and gradients. Because of the transparency of the cornea, lens, and vitreous, their position could be optically tracked by an ophthalmoscope equipped with a camera pointing to the eye. Microrobots envisions the platform being used for both clot-dissolving drug delivery and retinal vein cannulation. Thin film deposition, sputtering, 3D printing, stereolithography, and soft lithography are all techniques that can be used to microfabricate 3D magnetic devices with complex shapes. [29]

Nano robots

Nano robots are referred to as tiny robots or tiny machines which can traverse through the human body very easily. When a nano robot enters into the body of a patient, it would seek for infected cells and would repair them without causing any damage to the healthy cells. The nano manipulators of nano robots will penetrate into the damaged or targeted cell while the nano robots remain outside to avoid any possibility if present of causing damage to the intracellular skeleton. These nano robots provide an advantage such as extreme life prolongation through cell surgery after the entry of nano robots in human blood stream. Coordination is required across the board for better communication, acting, and sensing and poses a major research challenge. [30,32]

Benefits of using pharmaceutical robots

Design Advantage:

In the pharmaceutical business, slim, rapid, and flexible robots are suitable for pick-and-place and assembly tasks. Industrial robots can construct blood sugar kits and other custom orders thanks to vision technology. [31]

Advantage of Safety:

Robots safeguard the integrity of pharmaceutical products as well as the health of employees and patients. Toxic chemicals can be safely mixed using industrial robots. These specific robot models are intended for use in clean room environments. These models never contaminate product due to their sealed arm construction and decontamination with Hydrogen Peroxide Vapor (HPV). Low payloads pick and place jobs that would be too difficult for human workers are now in the hands of tenacious robots. [31]

Reliability:

All medication must be tracked and traced throughout the manufacturing process, according to the Food and Drug Administration (FDA). Pharmaceutical companies can meet these requirements more easily thanks to industrial robots. Robots, in a similar vein, reduce accidents and waste. Another reason for relying on robots is that they can work nonstop for 24 hours a day, seven days a week. [32]

Tirelessness:

A robot can complete a 96-hour project in ten hours with greater consistency and higher quality results.

Return on investment (ROI):

ROI has a quick turnaround. Furthermore, as quality and application speed improve, the benefits of increased production possibilities become available.

Accuracy:

Robotic systems outperform humans in terms of accuracy and consistency.

Affordability:

More pick and place robotic cells are being implemented for automation applications as technology progresses and more affordable robotics become available.

Quality:

Robots have the potential to significantly improve product quality. Every application is executed with precision and high repeatability. This level of consistency is difficult to achieve in any other way.

Production:

Throughput speeds increase with robots, which has a direct impact on production. Robots have the potential to produce more than human workers because they can work at a constant speed without stopping for breaks, sleep, or vacations.

Savings:

Increased worker safety results in financial savings. Employers have fewer concerns about healthcare and insurance. Robots also provide consistent performance, which saves time. Because their movements are always precise, less material is wasted.

Speed:

Robots work quickly and efficiently, wasting neither movement nor time. Robots can change productivity by increasing throughput without taking breaks or pauses.

Flexibility:

Packaging applications can be diverse. Robots are simple to reprogram. Changes in End of Arm Tooling (EOAT) development and vision technology have expanded packaging robots' application-specific capabilities.

Redeployment:

While robots' flexibility is typically measured by their ability to handle multiple product changes over time, they can also handle changes in product life cycles. [32]

Smaller is Better:

The costs of biological assays are high and rising. Robotics allows researchers to use small amounts of assays while also keeping samples safe when moving them around the laboratory.

Reduced contamination risk:

Removing people from the screening process reduces the possibility of contamination and dropped samples when handling them in laboratories. Robotics can complete these tasks much faster and with greater precision and accuracy.

Cost:

Payback periods for robotic equipment purchases in the pharmaceutical industry, given the relatively high hourly labour rates paid to employees, the number of production shifts, and the low cost of capital. The cost of a conventional robot installation, including all attachments, safety barriers, conveyors, and labour, might be approximately $200,000. If that robot were to replace four manual workers, each earning approximately $30,000 per year, the robot would be paid for in less than a year and a half through salary savings alone.

Efficiency:

Robotics has the potential to increase efficiency, which means that the drug's price will become more competitive. People are not as efficient as robots in pharmaceutical production, especially when wearing a protective suit. People wearing protective suits need more space to work in as well.

Can work continuously in any environment:

Another advantage of using robots in the laboratory is that they are resistant to many environments that would be hazardous to humans. A robot can operate with pinpoint accuracy 24 hours a day, seven days a week.

Increases productivity:

Because of the high-speed operation of robots, it also saves time and increases productivity throughout the day. [32]

Challenges faced are

Dangers and fears:

Although current robots are not thought to have progressed to the point where they pose a threat or danger to society, fears and concerns about robots have been expressed in a variety of books and films. The main theme is that robots' intelligence and ability to act may surpass that of humans, and that they may develop a conscience and a desire to take over or destroy the human race.

Expense:

Robots require a significant initial investment, especially when business owners limit their purchases to new robotic equipment. The cost of automation should be calculated in relation to a company's overall financial budget. Regular maintenance requirements can also be costly.

Return on investment (ROI):

The use of industrial robots does not guarantee success. Companies may struggle to meet their objectives if they do not plan ahead of time.

Expertise:

Employees will need to be trained in programming and interacting with the new robotic equipment. This normally necessitates both time and money.

Safety:

While robots may protect workers from some hazards, their mere presence can cause other safety issues. These new dangers must be taken into account.

Transferring of samples:

When samples must be transferred between different bays for different unit operations, this presents a challenge (for analysis, dispensing, processing, etc.) [32]

Job related challenges:

Some challenges are related to job loss, as the OECD (Organization for Economic Cooperation and Development) estimated in 2019 that 35% of jobs may be seriously affected by automation, and 14% of current jobs may no longer be available due to automation. [27] It is estimated that the jobs of low skilled workers may be affected. [6]

CONCLUSION

It has proven to be beneficial for incorporating robots into pharmaceutical day-to-day processes. Robots can work 24 hours a day and perform tasks three to four times faster than humans. As a result, robots can efficiently provide large quantities of products. Employees are freed from performing simple, repetitive tasks as a result of the availability of robots, allowing them to focus on developing new pharmaceutical products. Pharmaceutical robots have been discovered to be useful in a variety of fields, including research and development, pharmaceutical laboratories, picking and placing, packaging, filling, and so on. The use of robots in various sectors of pharmacy is rapidly increasing due to their extensive use. Pharmaceutical companies' ultimate goal is to produce high-quality products while increasing efficiency and lowering costs. Thus, robots can be of great assistance to businesses in terms of speed, flexibility, repeatability, precision, and accuracy. Furthermore, the use of industrial robots is growing by the day. According to the analysis, the number of installations is increasing year after year, and many organisations are considering pharmaceutical robots as a way to boost productivity, accuracy, and reliability. According to the world robotics 2020 industrial robots study, there was a 12% increase in industrial robots worldwide. It is expected that the number of industrial robots installed would increase by 12% in 2021 and 2022 as well. This is because, the costs of robots are falling, and even small manufacturing industries are now stepping forward to improve product quality by adopting the new robotics technology.

ACKNOWLEDGEMENT

I'd like to express our gratitude towards our mentor, Dr. Manisha Karpe madam (Pharmaceutics Department), for her unwavering support and encouragement during the project.

List of Abbreviations

SCARA - Selective Compliance Articulated Robot Arm
DNA - Deoxyribonucleic acid
NMR - Nuclear Magnetic Resosnance
IFR - International Federation of Robotics
TFP - Total Factor Productivity
R&D - Research and Development
H.T.S. - High Throughput Screening
PLC - programmable logic controllers
PC - Personal Computer
VME - VERSA-Module Euro card
EOAT - End of Arm Tooling
PCR - Polymerase Chain Reaction
ADME - Absorption Distribution Metabolism and Excretion
HPV - Hydrogen Peroxide Vapor
FDA - Food and Drug Administration
ROI - Return on investment
OECD - Organization for Economic Cooperation and Development

Competing Interests:
The authors declare no conflict of interest.

REFERENCES

1. Keisner A, Raffo J, Wunsch-Vincent S. Robotics: Breakthrough Technologies, Innovation, Intellectual Property. Foresight and STI Governance. 2016; 10 (2): 7–27.
2. Andras I, Mazzone E, Leeuwen FWB, De Naeyer G, Oosterom MN, Beato S, et al. Artificial intelligence and robotics: a combination that is changing the operating room. World J of Urology. 2019; 38 (10): 2359-2366.
3. Hussaina K, Wanga X, Omara Z, Elnourc M, Ming Y. Robotics and Artificial Intelligence Applications in Manage and Control of COVID-19 Pandemic. International Conference on Computer, Control and Robotics. 2021; 66-69.
4. Bloss R. Vision and robotics team up at the 2007 Show. Industrial Robot: An International J. 2008; 35 (1): 19–26.
5. Smith N. Robotics in Pharmaceutical Manufacturing. International Pharmaceutical Industry. 2018; 10 (4): 60-63.
6. Qureshi M, Sajjad R. A Study of Integration of Robotics in the Hospitality Sector and Its Emulation in the Pharmaceutical Sector. Health Science J. 2017; 11: 1-6.
7. Luthringer T, Aleksic I, Caire A, Albala DM. Developing a successful robotics program. Current Opinion in Urology. 2012; 22 (1): 40–46.
8. Graetz G, Michaels G. Robots at Work. *The Review of Economics and Statistics* 2018; 100 (5): 753–768.

9. Aspragathos NA, Koustoumpardis PN, Moulianitis VC, editors. Advances in Service and Industrial Robotics. Mechanisms and Machine Science. Alpe-Adria Danube; 2019.
10. Young K, Tuersley I, Vaidya A. UK robotic installations statistics for 2004. Industrial Robot: An International J. 2005. 32 (6): 444–448.
11. Albert N, Zachary TL, Oliver A, O'Connor. Economic Analysis of Technology Infrastructure Needs for Advanced Manufacturing Advanced Robotics and Automation. National Institute of Standards and Technology. 2016; 3-1 - 3-4.
12. Ballestar MT, Díaz-Chao Á, Sainz J, Sellens JT. Impact of robotics on manufacturing: A longitudinal machine learning perspective. Technological Forecasting and Social Change. 2021; 162: 120348.
13. Haegele M. Executive Summary World Robotics 2020. Service Robots.2020; 1-13.
14. Popkova EG, Sergi BS, editors. Digital Economy: Complexity and Variety vs. Rationality. Lecture Notes in Networks and Systems. Vladimir: Russia; 2020.
15. Kapoor Y, Meyer RF, Meyer BK, DiNunzio JC, Bhambhani A, Stanbro J, et al. Flexible Manufacturing: The Future State of Drug Product Development and Commercialization in the Pharmaceutical Industry. J of Pharmaceutical Innovation. 2020. 16 (1): 2–10.
16. Cao L, Russo D, Lapkin A A. Automated robotic platforms in design and development of formulations. AIChE J. 2021; 67 (5): 1-17.
17. Chapman T. Lab automation and robotics: Automation on the move. Nature. 2003; 421 (6923): 661–663.
18. Hedelind Mats M. J. How to improve the use of industrial robots in lean manufacturing systems. J of Manufacturing Technology Management. 2011; 22 (7): 891 – 905.
19. Fiorini P, Botturi D. Introducing service robotics to the pharmaceutical industry. Intel Serv Robotics. 2008; 1: 267–280.
20. Myers B. Key issues for establishing a robotics laboratory in the pharmaceutical industry. J of Automatic Chemistry. 1994; 16 (4): 117-119.
21. Bloss R. Review of new robot designs and the rise of remote programming in manufacturing technology. Industrial Robot: An International J. 2013; 40 (3): 213 – 217.
22. Barrett M, Oborn E, Orlikowski WJ, Yates J. Reconfiguring Boundary Relations: Robotic Innovations in Pharmacy Work. Organization Science. 2012; 23 (5): 1448–1466.
23. Bogue R. Robots in the laboratory: a review of applications. Industrial Robot: An International J. 2012; 39 (2): 113 – 119.
24. Boyd J. Robotic Laboratory Automation, SCIENCE. 2002; 295 (5554), 517-518.
25. Robert L. Sharp Richard G. Whitfield Lloyd E. Fox. Robotics in the Laboratory: A Generic Approach. Analytical chemistry. 1998; 60 (18): 1056A-1062A.
26. Bhatnagar N. Role of Robotic Process Automation in Pharmaceutical Industries. Handbook of Experimental Pharmacology. 2019; 497–504.
27. D'Arbeloff N. Improving the Integrity of Pharmaceutical Sterility Testing: A New Robotic Approach. Drug Development and Industrial Pharmacy. 1998; 14 (18): 2733-2740.
28. Carpi F, Pappone C. Magnetic robotic manoeuvring of gastrointestinal video capsules: preliminary phantom tests. Biomedicine & Pharmacotherapy. 2008; 62 (8): 546–549.
29. Fusco S, Ullrich F, Pokki J, Chatzipirpiridis G., Özkale B., Sivaraman K. M., Nelson B. J. Microrobots: a new era in ocular drug delivery. Expert Opinion on Drug Delivery. 2014; 11 (11): 1815–1826.
30. Halder A, Sun Y. Biocompatible propulsion for biomedical micro/nano robotics. Biosensors and Bioelectronic. 2019; 139: 111334.
31. Bragança S, Costa E, Castellucci I, Arezes P. A Brief Overview of the Use of Collaborative Robots in Industry 4.0: Human Role and Safety. Occupational and Environmental Safety and Health. 2019; 202: 641-650.
32. Teja TL, Keerthi P, Debarshi D, Niranjan Babu M. Recent trends in the usage of robotics in pharmacy. Indian J of Research in Pharmacy and Biotechnology. 2014; 1038-1043.

54878478451**211001**