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ARTIFICAL INTELLIGENCE IN PHARMA MANUFACTURING: A REVIEW

UNNATI. M. BOROLE, NAYAN. N. KADUSKAR, KARTIK. G. SHINDE

Indrayani Institute of Pharmaceutical Education & Research, Talegaon Dabhade.

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Abstract: In the world of pharmaceuticals, there is a vital role for robotics to play in the complicated processes of research and development, production, and packaging. Justification for robots ranges from improved worker safety to improved quality. A number of robot manufacturers have products specifically designed for this industry. Industrial robotics for pharmaceutical applications has a bright future. With a rapidly aging population that urgently requires sophisticated medical devices and newer drugs, robotics systems are increasingly adopted for improved productivity and efficiency to meet this growing demand. Robots in laboratory, life science and pharmaceutical applications perform tasks at rates beyond human capability. These robots function in potentially hazardous settings in proximity to biological dangers, the threat of radioactive contamination and toxic chemotherapy compounds. Robotics is called upon to assemble and package a variety of medical devices and implants as well as preparing prescriptions for mail-order pharmacies or hospitals. The Laboratory Robotics Interest Group (LRIG) is an international non-profit organization dedicated to the study and discussion of laboratory automation. LRIG activates the uses of laboratory automation in high-throughput screening, drug discovery, combinatorial chemistry, chemical synthesis, compound purification, compound distribution, data management, pharmaceutical dosage form sample preparation, dissolution testing, bio analytical technology, chemical analysis, solid phase extraction, validation and product formulation.

Keywords: Automation, Accurate, Flexible, Robust, Compact, Efficient, Easy to Use.

Corresponding Author: UNNATI. M. BOROLE

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INTRODUCTION

As demand for new drugs and medicines grows, pharmaceutical companies are continuously looking for new ways to increase productivity, leading to an increased reliance on automated equipment and robotics. These changes in ways of working will revolutionize many areas of the industry and are likely to have an effect on jobs. In this time of tremendous development in the Centers for Medicare and Medicaid Services, is 4.6% GDP up to $3.6 trillion in 2018, or $11,172 per person, and accounted for 17.7% of GDP.[1]

Available Robots first became commercially available in the early 1970, and were principally deployed inrugged and repetitive duties such as welding and handling in automotive manufacturing lines. We work specifically with machines for processing of sterile pharmaceuticals. Because of the need for product sterility and absolute precision, this field has always presented one of the most difficult challenges in design and use of automated systems. The increasing trend toward biological and genetically-based products, including live viruses, magnifies the protection that we must provide in our systems for the users of both the machines and the products that they process.

ARTIFICIAL INTELLIGENCE REVOLUTION: [2,3]

Driven by curiosity, scientists from a broad spectrum of disciplines continue to break new ground in the field of artificial intelligence. According to a study conducted by Stanford University, the future will see cars that drive themselves and robot housemaids becoming commonplace objects of our daily lives. Our timeline shows how human and artificial intelligence are gradually converging. It also makes clear that humans have character traits for which there are no artificial alternatives: curiosity, the courage to innovate, and inquisitiveness set them far apart from even the smartest computers.

1950-Just How Smart Are Machines?

Can a machine compete with the intellectual capacities of a human being? British mathematician Alan Turing conducted a test to find this out. In the so-called “Turing Test”, an analyst chatted with a computer and with a real person. If the analyst were unable to determine which answers came from the machine, and which from its human counterpart, the computer would pass the test and be considered intelligent.

1956-The Birth of the Concept of "Artificial Intelligence"

In the summer of 1956, John McCarthy, the American logician, computer scientist, cognitive scientist and author, organized a six-week conference on the subject of artificial intelligence at Dartmouth College in Hanover, New Hampshire. Since then, the so-called Dartmouth Conference has been seen as the starting point for all later research into artificial intelligence. Three years later, at the Massachusetts Institute of Technology (MIT), McCarthy and the American research scientist Marvin Minsky co-founded what today still stands as the leading institution in this field – the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL).

1966-Dialog Between Man and Machine

The German-American computer scientist Joseph Weizenbaum developed “ELIZA”, one of the first natural language processing computer programs. It analyzed the user’s input for keywords and provided answers to match the ones it found.

1969-Mobile Robots

Shakey, the first robot capable of autonomously navigating a room with the aid of a camera and sensors and responding to commands, was developed at the Artificial Intelligence Center of Stanford Research Institute. It was able to avoid obstacles and push objects around.

1997-Chess Computer Beats Grand Master

A computer by the name of “Deep Blue” became the first electronic chess player to beat a human World Chess Champion. Garry Kasparov, reigning World Champion at the time, lost 4:2 to the program designed by the American computer manufacturer IBM.

1997-The Robot Soccer World Cup

Thousands of scientists and students from every corner of the globe met in Japan to match their electronic soccer teams against each other.

2002-Domestic Robots

The American concern iRobot launches “Roomba”, the first robotic vacuum cleaner at an affordable price for private households (200 USD). It vacuums all the floors at a preset time and autonomously returns to its charging station.

2005-AI Researcher Predicts "Singularity" by 2045

Raymond Kurzweil, futurist, research scientist and director of engineering at Google, forecasts that “singularity” will be achieved by the year 2045. If things go the way he predicts, 2045 is the year in which the computing power of computers will draw level with that of the human brain.

2005-The First Autonomous, Self-Driving Automobile

“Stanley”, a modified VW Touareg entered by Stanford University, won the Grand Challenge of the Defense Advanced Research Projects Academy (DARPA). Stanley became the first completely autonomous land vehicle to master an obstacle course in the desert southwest of Las Vegas. The vehicle completed the 142-mile course in just under seven hours.

2010-Knowledge Contest: Machine Wins Against Human Challengers

The IBM computer by the name of "Watson" wins the gameshow "Jeopardy" against human world champions. It was able to analyze the host's questions faster and more precisely than its human challengers.

2011-The Cellphone That Talks

Apple presents "Siri" as a new feature of the iPhone 4s operating system. The speech recognition software is intended to act as a personal assistant and help iPhone users to make calendar entries, search for information on the Web or book flights.

2014-The First Computer Passes the Turing Test

The Russian chat-program Eugene Goostman, which simulates a 13-year old boy, is the first to pass the Turing Test.

2016-AI Invents Its Own Secret Language

The research unit Google Brain develops two computers that autonomously encrypt their inter-machine communication. Their developers, Martin Abadi and David G. Andersen from Google Brain call them Alice and Bob. With the aid of encrypted language, Alice can send Bob a "secret message" that Bob can decode but cannot be wiretapped by other networks. The encryption code for this was devised autonomously by the two computers.

2030-

According to the Stanford University Study, "Artificial Intelligence and Life in 2030", This Is What the Future Will bring

OBJECTIVES TO STUDY:

The main objective of the study is to highlight the integration of humanoid robots in the pharmaceutical industry at the medical dispensing stores by emulating robotic integration successes of the hospitality sector and ultimately developing strategies for its use in small, medium and large medical store provider's i.e., pharmacies. In addition to this, the advantages and disadvantages of this approach are assessed. And this research also provides basis to study the various factors that should be responsible for attracting the medical stores i.e., pharmacies, to use robotics at customer services, drug dispensing and cash counters.

To achieve the main objective, the following sub objectives are set: -

1. To find the current status of robotics in healthcare industry.
2. To assess the current status of robotics in pharmaceutical sector.

3. To get an overview of robotic integration in the hospitality sector and its emulation in the pharmaceutical sector for medical dispensing jobs.

WORK SHARING WITH ROBOT COLLEAGUES [2,3]

According to researchers at Stanford University, AI will replace humans in many kinds of jobs – for instance, taxi or truck drivers. Nevertheless, rather than fulfilling entire job profiles, robots will tend to take on more specific tasks. This applies by no means only to unskilled jobs.

According to the Harvard Business Review, AI will also redefine management as we know it today: Robots are now colleagues, and the division of tasks is clearly defined. While machines increasingly handle administrative, coordinative, and controlling tasks, human employees are given room to concentrate on their unique, inventive skills, such as experimentation, improvisation and innovation. They make decisions and develop strategies. After all, it is factors like these that continue to set human beings apart from their electronic counterparts: They possess social competency and creativity – they can combine ideas in new ways and get one innovation after another on the road to success. In other words: they are led and inspired by curiosity.

WHAT IS A ROBOT?

Robot is a mechanical or virtual artificial agent. In practice, it is usually an electromechanically system which, by its appearance or movements, conveys a sense that it has intent or agency of its own. The word robot can refer to both physical robots and virtual software agents, but the latter are usually referred to as bots. There is no consensus on which machines qualify as robots, but there is general agreement among experts and the public that robots tend to do some or all of the following: move around, operate a mechanical arm, sense and manipulate their environment, and exhibit intelligent behavior, especially behavior which mimics humans or animals.

The International Organization for Standardization gives a definition of robot in ISO 8373: "an automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications."[4]

Furthermore to giving hands-on patient care, robots have also worked as mentors and lifts for patients of various ages. Inventors forms Japan created "ROBOT FOR INTERACTIVE BODY ASSISTANCE "for caring patient weighing a maximum of 1341bs to bedsides and wheelchairs using built in sensors and foam support technology.[5]

How Robot enter into pharmaceutical industry?

Robots first became commercially viable in the early 1970, and were principally deployed in rugged and repetitive duties such as welding and handling in automotive manufacturing lines. The first ABB robot, for instance, was installed in 1974 in the automotive field. Since then, more than 150000 have been installed globally including a large proportion in the pharmaceutical field. Many of these early clinical robots were little more than programmable liquid handlers that provided a mechanical arm for high-throughput screening (HTS) systems, where the arm moved samples from one instrument to another. The industry was slow to adopt robots into manufacturing and packaging processes. One reason for this was, undoubtedly, the industrial nature of robots. [6]

SOME COMMONLY USED ROBOTS IN PHARMACEUTICAL INDUSTRY:

1. Cylindrical Robot for High Throughput Screening:

ST Robotics presents a new 4-axis cylindrical robot for DNA screening in applications such as forensic science, drug development, bacterial resistance, and toxicology. The R19 is a totally new design that may be supplied as a precise 4-axis robot, or as a simple 2-axis plate mover. It is usually mounted on a track, which can be up to five meters long, surrounded by various laboratory instruments. The robot moves samples from instrument to instrument according to a protocol decided by the user. Advanced drives create swift and smooth motion while maintaining quiet operation in the lab environment. Like all Sands Technology robots, the new R19 is a totally reliable workhorse, tested to ISO 9000 quality assurance. [7], [8], [9]

The KUKA KR 1000 Titan is the company's latest product and with its heavy weight capabilities has earned an entry in the Guinness Book of Records. The KR 1000 Titan is the world's first industrial robot that can lift a payload of 1000 kilograms with a reach of 4000 mm and will be handling a Chrysler Jeep body. The Titan is ideally suited to handle heavy, large or bulky work pieces. The heavyweight champion was developed for sectors such as the building materials, automotive and foundry industries [7], [10].

2. Food/Pharmaceutical Handling System with M-430iA Robot Arms and Visual Tracking, FANUC Ltd.:

This robotic food and pharmaceutical handling system features a visual tracking system and a pair of multi-axis robot arms that each can accurately pick up 120 items per minute as they move along a conveyor belt. The arms can work non-stop 24 hours a day, are resistant to acid and alkaline cleaners, and feature wrists with plastic parts that eliminate the need for grease. The sanitary design provides the cleanliness required of machines tasked with handling food and medicine. With a proven record of success in reducing manufacturing costs and improving quality, about 150 systems have been sold to manufacturers worldwide since October 2006[7],[11],[12]

3. Pharmaceutical Container Replacement Robot:

Tsumura & Co. Fuji Heavy Industries, Ltd.

This autonomous robot is capable of navigating tight spaces at factories for the purpose of transporting containers used in the pharmaceutical manufacturing process. The robot can automatically connect itself to large containers (or cases packed with products) weighing up to 200 kilograms (440 lbs.) for transport. The robot only needs to be charged once per day, it can be freely programmed and customized to suit the manufacturing process, and it is safe and easy to use on existing production lines. Three robots are now working on production lines at a pharmaceutical factory, where they have reportedly boosted productivity by30%. [7], [10] A pair of robots to recognize and handle small containers, etc. on a conveyer using visual tracking and arm control capabilities, FANUC Ltd.'s:

FANUC Ltd's technology that allows a pair of robots to recognize and handle small containers, etc. on a conveyer using visual tracking and arm control capabilities won the METI Minister Award (Grand Prize), which is granted to a technology that wins the highest appreciation from juries. This technology primarily targets applications at manufacturing facilities of food and medical equipment. [7], [13]

Metal Detector Targets Pharmaceutical Industry:

Incorporating Quadra Coila system, Goring Kerr DSP Rx screens pills and capsules at out feed of tablet presses and capsule filling machines. It offers adjustable in feed heights from 760-960 mm and angular adjustments of 20-40°. System features open- frame design and polished, stainless steel finish. For maximum hygiene, pneumatics and cables are contained within unit stand. Mounting bars have round profiles to remove risk of debris and bacteria traps. [7], [14], [15]

QuadraCoila system, Goring Kerr DSP Rx

- **Labeling System targets Pharmaceutical Industry:**

Pharmaceutical Grade Labeling System

Featuring stainless steel construction, Pharmaceutical Grade Labeling System can label variety of oval plastic and glass containers from 75-450 ml at speeds up to 450 ppm. It includes sanitary style conveyor, bar code scanner, eject station with eject verification, and Video Jet laser imprinter for date and lot number on each label. Options include Vision System by Systec, Allen Bradley PLC control, color touch screen operator interface, and full validation package. [7], [16]

1. Six-Axis Robots suit Class 1 Clean Room Applications:

Running on Smart Controller(TM) CX controls and software platform, Adept Viper(TM) s650 and Adept Viper(TM) s850 bring precision motion and 6-axis dexterity to clean room assembly, handling, testing, and packaging applications. With integrated vision and embedded networking, robots target customers in solar, disk drive, LCD, semiconductor, and life sciences markets. [7], [16]

Smart Controller(TM) Space Ceiling Mounted Robot:

Adept Technology has introduced a ceiling-mounted version of its s800 series Cobra robot. The inverted robot offers high-speed packaging and assembly with a wider reach, while leaving a much clearer working area.

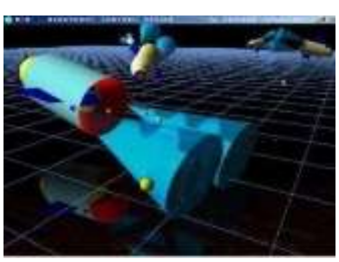
The new robot offers several advantages over its predecessor, which is floor mounted and traditionally sits beside the convey or belt or packing line. While the Cobra s800 Inverted Robot has a reach of 800mm, the same as the previous floor-mounted model, being mounted on the ceiling above the conveyor effectively doubles this reach.

The machinery can also be supplied with a vision system of up to four cameras, which identify the position of products on the conveyor belt and link back to the robot so it can accurately pick up and orientate the product for assembly or packaging [17], [9].

- **Nano robots**

A new approach within advanced graphics simulations is presented for the problem of Nano-assembly automation and its application for medicine. The problem under study concentrates its main focus on Nano robot control design for molecular manipulation and the use of evolutionary agents as a suitable way to enable the robustness on the proposed model. Thereby the presented works summarize as well distinct aspects of some techniques required to achieve successful integrated system design and 3D simulation visualization in real time. [18]

Recent developments on the field of biomolecular computing has demonstrated positively the feasibility of processing logic tasks by bio-computers, which is a promising first step to enable future Nano processors with increasingly complexity. Studies in the sense of building biosensors and Nano-kinetic devices, which is required to enable Nano robots operation and locomotion, has been advanced recently too. Moreover, classical objections related to the real feasibility of nanotechnology, such as quantum mechanics, thermal motions and friction, has been considered and resolved and discussions about the manufacturing of Nano devises is growing up. The control design and the development of complex integrated Nano systems with high performance can be well analyzed and addressed via simulation to help pave the way for future use of Nano robots in biomedical engineering problems [19].



More specifically, nanorobotics refers to the still largely hypothetical nanotechnology engineering discipline of designing and building **Nano robots**, devices ranging in size from 0.1- 10 micrometers and constructed of nanoscale or molecular components. As no artificial non- biological Nano robots have yet been created, they remain a hypothetical concept. The names **Nano bots**, **Nanoids**, **Nanites** or **Nano mites** have also been used to describe these hypothetical devices.

An example is a sensor having a switch approximately 1.5 nanometers across, capable of counting specific molecules in a chemical sample. The first useful applications of Nano machines, if such are ever built, might be in medical technology, where they might be used to identify cancer cells and destroy them. Another potential application is the detection of toxic chemicals, and the measurement of their concentrations, in the environment.

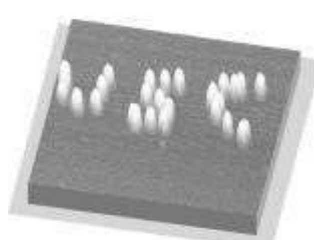
Nanotechnology promises futuristic applications such as microscopic robots that assemble other machines or travel inside the body to deliver drugs or do microsurgery.

Taking inspiration from the biological motors of living cells, chemists are learning how to utilize protein dynamics to power micro size and Nano size machines with catalytic reactions [20].

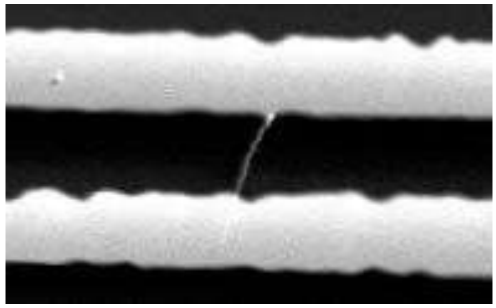
NANOROBOTS: WHAT ARE THEY?

Nano robots are Nano devises that will be used for the purpose of maintaining and protecting the human body against pathogens. They will have a diameter of about 0.5 to 3 microns and will be constructed out of parts with dimensions in the range of 1 to 100 nanometers. The main element used will be carbon in the form of diamond / fullerene nanocomposites because of the strength and chemical inertness of these forms. Many other light elements such as oxygen and nitrogen can be used for special purposes. To avoid being attacked by the host is immune system, the best choice for the exterior coating is a passive diamond coating. The smoother and more flawless the coating, the less the reaction from the body’s immune system. The powering of the Nano robots can be done by metabolizing local glucose and oxygen for energy. They will have simple onboard computers capable of performing around 1000 or fewer computations per second. This is because their computing needs are simple. Communication with the device can be achieved by broadcast-type acoustic signalling.

Nanorobotics Examples



Pattern of 15 nm Au particles built by AFM manipulation



In2O3 nanowire sensor for $NO_{2built}$by CVD

Fig-2: Nano CD: LMR in ASCII encoded in the positions of Nano manipulated 15nm Au particles

A navigational network may be installed in the body, with station keeping navigational elements providing high positional accuracy to all passing Nano robots that interrogate them, wanting to know their location. This will enable the physician to keep track of the various devices in the body. These Nano robots will be able to distinguish between different cell types by checking their surface antigens (they are different for each type of cell). This is accomplished by the use of chemotactic sensors keyed to the specific antigens on the target cells [21]. They can also be removed by active scavenger systems. This feature is design- dependent.

FIELDS OF APPLICATION:

1. To cure skin diseases, a cream containing nanorobots may be used. It could remove the right amount of dead skin, remove excess oils, add missing oils, apply the right amounts of natural moisturizing compounds, and even achieve the elusive goal of '*deep pore cleaning* ‘by actually reaching down into pores and cleaning them out. The cream could be a smart material with smooth-on, peel- off convenience.

2. A mouthwash full of smart nanomachines could identify and destroy pathogenic bacteria while allowing the harmless flora of the mouth to flourish in a healthy ecosystem. Further, the devices would identify particles of food, plaque, or tartar, and lift them from teeth to be rinsed away. Being suspended in liquid and able to swim about, devices would be able to reach surfaces beyond reach of toothbrush bristles or the fibres of floss.

3. Devices working in the bloodstream could nibble away at arteriosclerotic deposits, widening the affected blood vessels. Cell herding devices could restore artery walls and artery linings to

health, by ensuring that the right cells and supporting structures are in the right places. This would prevent most heart attacks.

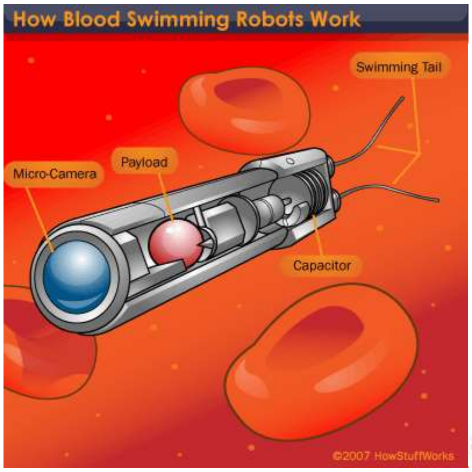


Fig-3: Nano robots may treat conditions like arteriosclerosis by physically chipping away the plaque along artery walls [23]

Treating arteriosclerosis: Arteriosclerosis refers to a condition where plaque builds along the walls of arteries. Nano robots could conceivably treat the condition by cutting away the plaque, which would then enter the bloodstream

Breaking up blood clots: Blood clots can cause complications ranging from muscle death to a stroke. Nano robots could travel to a clot and break it up. The robot must also be small enough so that it doesn't block the flow of blood itself.

Fighting cancer: Doctors hope to use Nano robots to treat cancer patients. The robots could either attack tumors directly using lasers, microwaves or ultrasonic signals or they could be part of a chemotherapy treatment, delivering medication directly to the cancer site.

Doctors believe that by delivering precise doses of medication to the patient, side effects will be minimized without a loss in the medication’s effectiveness.

Applications:

1. Current status of robotics in pharmaceutical sector:

Vision technology lets industrial robots to place together customized orders and perform jobs like assemble blood sugar kits. Pharmaceutical industrial robots are particularly beneficial for drug discovery jobs, packaging and handling test tubes. [23]

2. Robotic Dispensing:

One of the main problems faced by pharmacies is the loss of time management and search for drugs, causing negative situations as the delays, the lack of time for a more personalized attention and, as a result, the loss of customers. This problem and the need for improvement in the management of the stocks have made to appear the systems os automatic dispensing of pharmaceutical products. Consulted pharmacy graduates have found that approximately 60% of the time spend on care customer invest it in search and dispense the medication. [24] In Germany, an industrial robotic device had been adapted to work in a rural community pharmacy. In this pharmacy there was a need to free space in order to create an area for counselling patients and to expand clinical services for the local community. Installing the robotic picking device in the basement created the space required.[25]

3. Research and Development (R&D)

Robots now also play an essential role in the development of new drugs. In high throughput screening (H.T.S) for instance, millions of compounds are tested to determine which could become new drugs. There is a need for the use of robotics to test these millions of compounds. The use of robotics can speed this process up significantly, just as they can any other process where a robot replaces a person completing any repetitive task.

4. Laboratory Robotics:

This new technology allows human talents to be concentrated on sample selection and submittal, and scrutiny of the resulting data, rather than mono to us tasks that lead to boredom and mistakes. The desired result of this automation is of course better data and reduced costs. Using laboratory robotics, new experimental procedures are eliminating human tedium and miscalculation in washing and transferring. This includes experiments in radioactive, fluorescent, and luminescent analysis. Laboratory robotics is being increasingly applied in pharmaceutical development to help meet the needs of increasing productivity, decreasing drug development time and reducing costs. Three of the most common geometries for laboratory robots are: Cartesian (three mutually perpendicular axes); cylindrical (parallel action arm pivoted about a central point); and anthropomorphic (multijointed, human-like configuration).

5. Control System:

Most robots have onboard controllers that communicate with other machines programmable logic controllers (PLCs) or with personal computers (PCs) networked to the line. Robot controller is an industrial VME bus controller that connects to PCs for networking and for graphical user interface.

6. Vision Systems:

A vision system provides valuable tool for determining the accuracy of text and graphics in pharmaceutical and medical packaging. The chief benefit offered by adding a robot to the vision system is speed. It inspect insert in less than two minutes. The same inspection performed by one operator and checked by a second operator could take from 30 minutes to an hour.

7. Sterilization and Clean Rooms:

Robotics can be adapted to work in aseptic environments. Clean room robots have features that protect the sterile environment from potential contamination. These features include low – flake coatings on the robotic arm, stainless steel fastners, special seal materials, and enclosed cables. Clean room robots reduce costs by automating the inspection, picking and placing, or loading and unloading of process tools. Benefits of robot use in the clean room include:

- Robots reduce scrap by minimizing mishandled or dropped parts.
- Robots minimize scrap caused by contamination.
- Robots reduce the use of clean room consumables such as bunny suits.
- Robots reduce the amount of costly clean room space by eliminating aisles and access ways typically required for human clean room workers. Robots can also be enclosed in mini environments. This permits relaxed cleanliness throughout the remainder of the plant.
- Training costs and clean room protocol enforcement are minimized. [26], [27].

8. Flexible Feeding:

Robots are also better than hard automation at flexible feeding, at ask that involves handling multiple types of products or packages whose orientation always varies. Traditionally, packing lines have used high-speed, automated bowl feeders that vibrate parts and feed them to fillers, labelers, or product transfer mechanisms. Bowl feeders, however, can't always handle variety of products at once, and their vibration can damage fragile parts.

9. Packing Operations:

Packaging processes, like other pharmaceutical operations, benefit from the speed and repeatability that automation brings. Robotics in particular provides flexibility and accuracy. In some packaging applications such as carton loading, robotics also performs more efficiently than dedicated machines. Pharmaceutical packaging machines are often custom- designed to handle specific product configurations such as vials.

Advantages of Industrial Robot:

- **Tirelessness:** A robot can perform a 96 man-hour project in 10 hours with more consistency and higher quality results.

- **Return on investment (ROI):** There is quick turn-around with ROI. Plus, with the increase in quality and application speed, there are the benefits of increased production possibilities.

- **Accuracy:** Robotic systems are more accurate and consistent than their human counter parts.

- **Reliability:** Robots can work 24 hours a day, seven days a week without stopping or tiring.

- **Affordability:** With the advancements in technology and affordable robotics becoming available at less cost, more pick and place robotic cells are being installed in automation applications.[28]

- **Quality:** Robots have the capacity to dramatically improve product quality. Applications are performed with precision and high repeatability every time. This level of consistency can be hard to achieve any other way.

- **Production:** With robots, throughput speeds increase, which directly impacts production. Because robots have the ability to work at a constant speed without pausing for breaks, sleep, vacations, they have the potential to produce more them a human worker.

- **Safety:** Robots increase workplace safety. Workers are moved to supervisory roles, so they no longer have to perform dangerous applications in hazardous settings.

- **Savings:** Greater worker safety leads to financial savings. There are fewer healthcare and insurance concerns for employers. Robots also offer untiring performance which save valuable time. Their movements are always exact, soles material is wasted. [28]

- **Speed:** Robots work efficiently, without wasting movement or time. Without breaks or hesitation, robots are able to alter productivity by increasing throughput.

- **Flexibility:** Packaging applications can vary. Robots are easily programmed. Changes in their End of Arm Tooling (EOAT) developments and vision technology have expanded the application specific abilities of packaging robots.

- **Reduced chances of contamination:** Removing people from the screening process reduces the potential for contamination and potential for drop samples when handling them in laboratories. Robotics performs these tasks much faster with more precision and accuracy.[27], [29]

- **Cost:** Paybacks for the purchase of robotic equipment in the pharmaceutical industry, given the fairly high hourly labor rates paid to employees, number of production shifts, and the low cost of capital. A typical robot installation, complete with accessories, safety barriers, conveys, and labor, could cost around $200,000.If that robot were to replace four manual workers each earning approximately $30,000 per year, the robot would be paid for through salary savings alone in a little more than a year and a half.[30], [31]

- **Increase Efficiency:** Robotics can increase efficiency, which means the price of the drug itself will become more competitive. When it comes to pharmaceutical production, people are not as efficient as robots, especially when they are wearing a protective suit. People in protective suits also require more room to work in.

INDUSTRIES WHICH USES ROBOTS:

1. MERCK:

Robots have been successfully used by Merck on bottling lines to place dispenser caps onto bottled allergy medications. The robots are capable of operating at 120 cycles per second, with ten variants of the bottle capable of running on the system.

CONCLUSION:

Robotics which has emerged as a newer and advanced field in pharmacy has gained much non-popularity in pharma industry. Their applicability in different fields of pharma industry is appreciated. It is accepted that in future the robotics would play a vital role for development and growth of pharmaceutical industry for more than two decades. In medical device manufacturing, robotics plays an active role in assembly. The manufacturing process is highly regulated and approved by Food and Drug Administration (FDA). Manufactures use robots to reduce cost. Robotics performs more important tasks in surgical procedures. Tele-operated surgical robotics is used to augment the surgeon. Robots are used for delivery of radiation and for proton therapy. The goal is to administer the smallest dose of radiation as possible to the precise location. Robots are very precise, positioning equipment and patients accurately in three dimensional spaces. Robots are loading and unloading injection molding machines, assembling medical devices and polishing implants. There is increased activity for bench-top robotics performing various protocols. These stations are reprogrammable and many are complex. Robotics is essential to modern scientific or commercial research and experimentation.

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