A Brief Review of the Industrial Manipulators in Product-line

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Abstract: This article provides a comprehensive overview of the industrial manipulator, brief history, classification, application, and design process. It is crucial for designers, engineers, and researchers to be familiar with various types of industrial manipulators and applied codes used by engineering companies, as well as key factors that need to be considered during the design process. This paper provides a basic understanding of the industrial manipulators in order to optimize the current manipulator design and propose new designs. To optimize and construct the design, it is necessary to understand different types of errors related to the design and the codes that lead us to a suitable design. These error types and codes have been explained in detail in this document.

Keywords: Industrial manipulator; Design process; Ergonomics; Robotic manipulator; Employee satisfaction.

1. Introduction

An industrial manipulator is a rigid machine arm made of steel that performs complex and difficult tasks, movements and rotations to aid operators in the industrial product line. The system is operated by a human operator and enables precise and efficient movement of the machine for lifting, lowering, rotating or carrying an object. Customer satisfaction is primarily determined by the experience of the employee. Employee productivity and safety are affected by improper assembly or working in an uncomfortable environment for long periods of time, which is most likely to result in human error and low productivity. The digital assembly simulation is one of the most powerful approaches to avoid this problem from the outset (Zhao, Zhang, Wu, & Yan, 2016). With the globalization and intensification of technology and economic growth in this age, manufacturers and industrial companies with mass production are constantly challenged to produce the most diverse complex requirements of customers. These put the workers under massive work pressure and there was an obstacle to achieving the desired productivity. Therefore, the manufacturer often encounters obstacles as listed below:

- A product is too heavy for workers to move manually.

- An object has to be brought to a very precise position that is not convenient or quickly accessible for a worker.
- A worker is at risk of manually moving a product.
- A job in production is difficult to do efficiently without disrupting the entire product line.

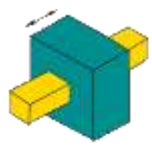
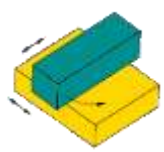
Ergonomics is a method of designing or assembling environments, products and facilities to suit the users who would use them. It involves designing something that has to do with people, work areas, recreation, health and safety (Soares & Rebelo, 2016). Industrial manipulators and robotic arms are used to reduce or completely solve these problems while maintaining employee satisfaction in the workplace and the product range of manufacturing companies. As risky, repetitive, and precise operations have been supported by robotic manipulators, it has been used to increase productivity and give the product line a flexible character. For the first time, the conceptual idea for the robotic manipulators was presented just after the 1959s by G. C. Devol (U.S. Patent 2988237) called the Programmed Article Transfer. However, it was underrated at the time and no courtesy was given by Engineers and industries, till the time J. Engelberger joined him and they started a company to produce these manipulators via (Unimation Inc) company. This became possible after the turning point where George Devol received (U.S. Patent 2988237) for a programmable robotic arm in 1961. By the 1960s they successfully launched the first industrial manipulating robot and became the founders of industrial manipulators through Unimation Inc (Ross, Fardo, & Walach, 2018). It was a very vital factor for the invention and execution of the robotic manipulator arms in the manufacturing industries. Where the industrial robot system is the main discipline for robotic manufacturers, a lot of continuous work and research is being established to boost the efficiency of the robot, cut the price of the robot, and add new features. Multi-robot control, safe control system, force control, 3D vision, remote robot monitoring and communication systems are growth areas that are receiving a lot of attention today (Brogårdh, 2007).

At present, as per the Robotic Industry Association, there were around 120,000 utilized industrial robots in the United States alone. In the five years from 1995 to 2000, the industry saw tremendous growth with record sales in 1999 and 2000 and new sales of $ 1,000,000,000 (Khoo, 2008). Research shows that the use of industrial robotic manipulators has grown rapidly, helping the manufacturing industry around the world in their jobs.

2. Classification of the industrial manipulator

Manipulators have been classified differently with different properties, such as the structure, the functional principle, the load-bearing capacity, the working area, etc. However, before talking about different types of industrial manipulators, an awareness of joints is needed. There are two references to a joint. The first is the fixed original source frame. The second frame of reference is not stationary and shifts relative to the first frame of reference as a function of the joint position, which determines its configuration.

Table 1. Types of joints (Tsai, 1999)

Name of joint	Configuration	Description
Revolute-joint		They are like pin joints, they rotate around the pin.
Cylindrical-joint		It has an axis on which it enables both rotation and translation at a joint.
Prismatic-joint		Allows uniaxial linear movement on the joint.
Spherical-joint		This joint has a freedom of rotation of 3 degrees with respect to the center of the joint. it is also known as a ball joint.
Planar-joint		This connection is used for a relative translational movement in a plane and a rotation around the vertical axis in the same plane.

Manipulators can be identified using several parameters. Figure 1 shows the classification of manipulators based on the movement properties and the kinematic properties of the structure (Tsai, 1999).

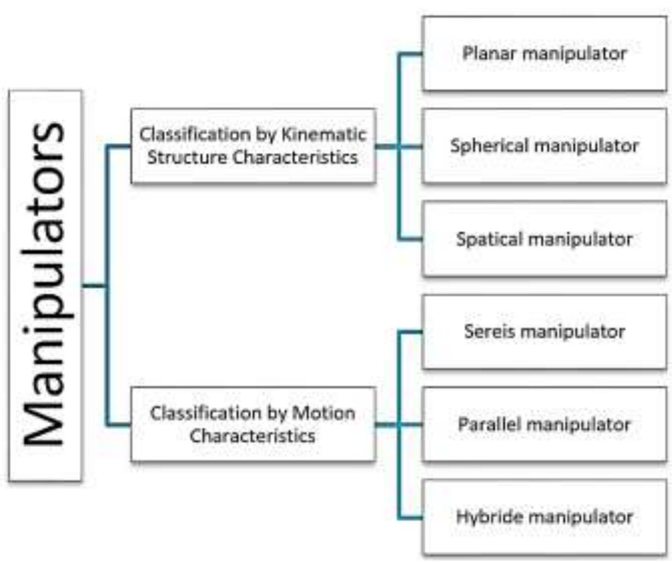


Figure 1. Classification of industrial manipulator

3. Application of industrial manipulator and robotic manipulator

On the one hand, manipulators play an extensive role in the innovations of various industries and help manufacturers and service providers to develop and improve their work processes, to keep workers satisfied and to significantly reduce dangers and risks in the workplace. Figure 2 shows the general uses of industrial manipulators. On the other hand, there are numerous variants of manipulators in terms of their properties of structure, movement, resilience and precision. Hence, the application of industrial manipulators covers a wide area, from the product lines of manufacturing companies to medical science, and from aerospace to biotech laboratories. A number of uses for industrial manipulators are listed below:

- **Vehicle industries:** Industrial manipulators are used in the automotive industry for arc welding, spot welding, material handling, painting, assembly, etc.
- **Medical application:** The use of robots in medicine can only be traced back 30 years. The use of robots in surgery arises from the need for evolution to serve the following purposes: the virtual existence of the sergeant and predictable and efficient performance outcomes. In 1985, the PUMA 200 was the first used simply to on a human patient (Ghezzi & Corleta, 2016).
- **Aerospace:** In industrial and medical robotics, visual servo, that is, the use of one or more cameras and a computer vision system to monitor the location of a robot end-effector, is becoming a common practice. This topic seems ready to be carried over to the aerospace industry in the design processes of cameras and frame grabbers (Ferrara & Scattolini, 2004).

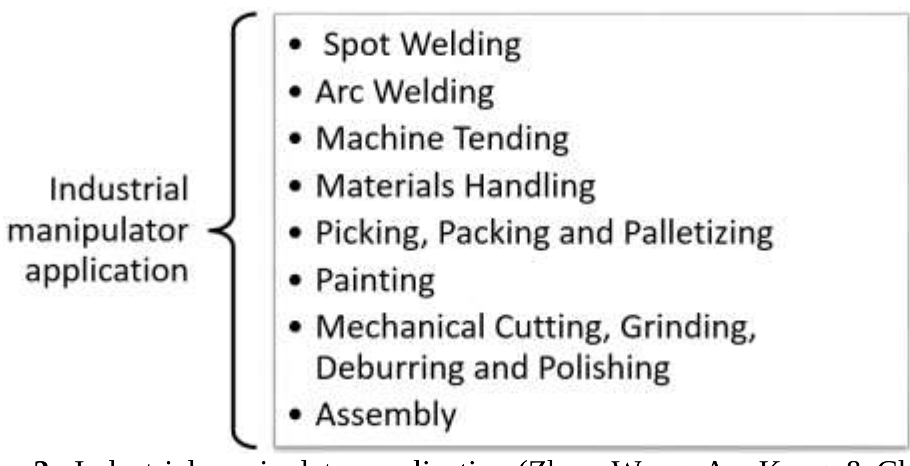


Figure 2. Industrial manipulator application (Zhou, Wang, Au, Kang, & Chen, 2021)

4. The design process of the industrial manipulator

In engineering, the design cycle is a combination of phases that guide the design team in solving problems. The process of design is dynamic, which suggests that we replicate the process as many times as necessary to achieve a reliable design, making changes along the way on the cycle as we troubleshoot the failures and digging up new possibilities for design to arrive at viable alternatives. As a matter of fact, this process and steps have been followed for all engineering designs which are shown in Figure 3.

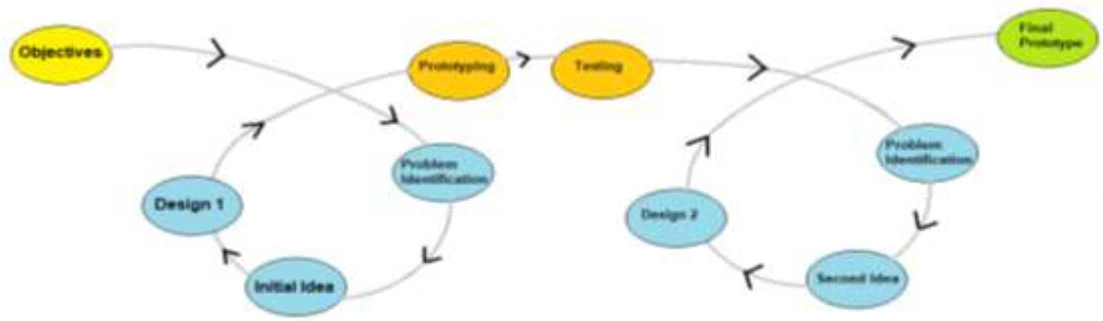


Figure 3. Engineering design cycle

1. **Objective:** Before we can start our design, it is necessary to specify the goals of the design and understand our optimal goal. And we should fully understand what society's need we are satisfying.
2. **Problem identification:** At this stage, engineers try to understand the problem by asking questions. These questions include: What is the problem that needs to be solved? What has to be designed? What is the service we are looking for? And what are the requirements and restrictions for the project?
3. **Research, brainstorming, and coming up with an Idea**: The previous literature is examined from different perspectives and special fields in order to find out which goods or solutions already exist or which innovations can be adapted to your requirements. And use our creativity to develop solution concepts.
4. **Designing**: This is the hardest step for multiple people. Reevaluate the requirements, constraints and analysis of the previous phases, discuss your best ideas, choose a solution and proceed with the original design taking into account all calculations, given geometry and estimated parameters. We also conduct simulations in the design process before the prototyping.
5. **Prototyping**: In this phase, the first design is produced with specified parameters and a specified production process. When prototyping, engineers encounter obstacles and need to make some adjustments to get their desired prototype.
6. **Examining the prototype**: At this stage we analyze the prototype and run a series of tests to see if the designed and built model works and if it meets the requirements or not. Converse and get reviews on the outcome. Understand and explore what works, what doesn't, or what could be improved.

If we don't get the result we want in the prototype test, we will investigate how the idea could be improved. Make revisions, where do we still have room for improvement in order to make our design as good as possible? Iterate our concept and then repeat all the steps for a second loop (Ullman, 1992). During the operating process, the dynamic systems of industrial manipulators are exposed to bending, axial and torsional loads, among other things. Structural stiffness is believed to be critical to noise reduction, general stability, friction reduction, accuracy, and time. The topology optimization of components helps to optimize the dynamic efficiency as well as the structural stability of a manipulator. There are several significant influencing factors that must be considered in order to achieve a suitable industrial manipulator design, as can be seen in Figure 4 below.

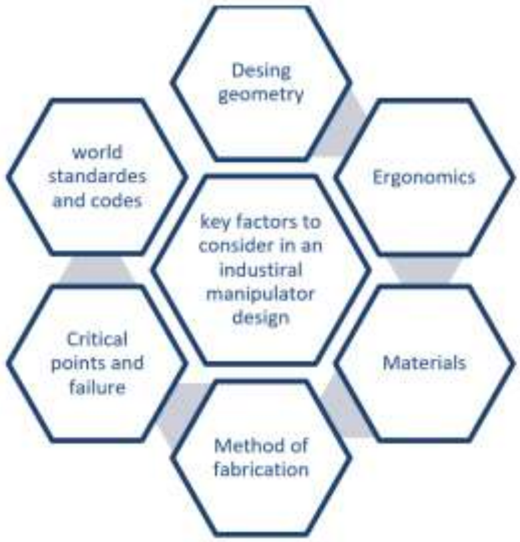


Figure 4. Key factors in the design of industrial manipulator

5. Industrial Manipulators failures

Any component failure during the operation of a manipulating system is a cause for concern. The failure of joint excitation and structural failure are the sources of these concerns. Although industrial robots and manipulators improve the ergonomics of a production area, there is a fear that industrial robots and manipulators create a dangerous work environment and injure the employees (Cline & Pai, 2003). The following are some of the most critical failures of the industrial manipulator in Figure 5.

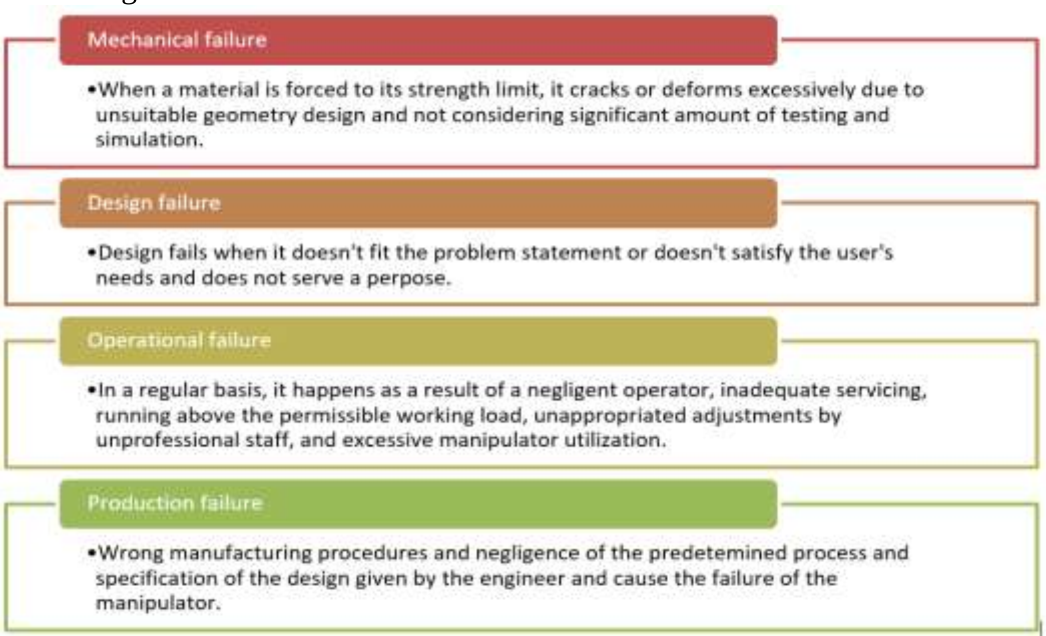


Figure 5. Industrial manipulator failures

6. World standards of industrial manipulators

Standards are the collective intelligence and experience of individuals who understand the expectations of the entities they embody, such as manufacturers, consumers, investors, trade unions, and authorities, with competence and skills in their particular department (Haluszka & Mansour). If a product or a manufacturing company is certified according to national standards or international IOS standards, consumers can be sure that the product has been manufactured in the best possible way, taking into account certain safety and quality standards. Each globally recognized standard has its own rule and is focused on a specific topic, so each standard has a different number. Some of the most common standards in the manufacturing industry are shown in Figure 6.

There are a variety of technical standards and codes that cover the design, construction, inspection, marking, maintenance, and repair of industrial manipulators. These standards can vary from place to place, but Figure 6 shows the most commonly used codes in the world.

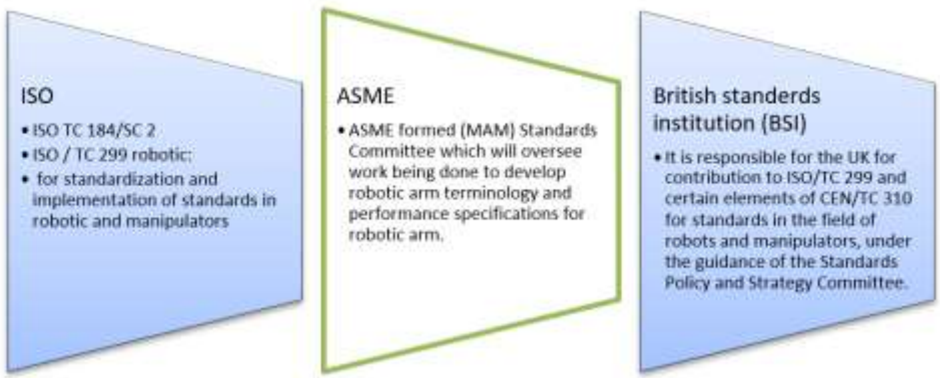


Figure 6. World standards of industrial manipulators (Ullman, 1992),(Sadegh & Horowitz, 1987),(Haluszka & Mansour),(Biffl, Schatten, & Zoitl, 2009)

7. Conclusion

In summary, the contribution of industrial manipulators to the manufacturing industry has been significant in terms of developing technology, the use of ergonomics, and employee satisfaction. Simultaneous fulfillment of various requirements in the production line from safety, taking on complex tasks, ergonomics application to mass production and employee satisfaction. Despite new applications for the industrial manipulator in the various sectors, the industrial manipulators with advanced and optimized design would be widely used around the world to overcome the obstacles of bending load, torsion, structural stability and dynamic efficiency.

ISO and various engineering companies have developed codes and standards for industrial manipulators, which on the one hand help and guide designers and on the other hand ensure the safety of users and operators. It is quite difficult to come up with a new design for the industrial manipulators, however, there is still a lot of software that does numerous types of simulations. These help the engineers to optimize the current design and its efficiency, as well as these simulations and the application of ergonomics help engineers to obtain new possible designs for the industrial manipulators.

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