DESIGN AND ANALYSIS OF ROBOTIC ARM FOR FLEXIBLE MANUFACTURING SYSYTEMS

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Abstract

Nowadays Robots play a vital role in all the activities in human life including industrial needs. In modern industrial manufacturing process consists of precise and fastest proceedings. Human operations are needed to perform a variety of tasks in a robotic system such as set-up, programming, trouble shooting, maintenance and error handling activities. Hazardous conditions exist when human operators intervene into the robotic work zones. The robotic arm consists of stepper motors which are controlled by the microcontrollers which are pre-programmed for the operations that are to be performed by the arm. The end effector used in our project is two finger gripper which is used to clamp the workpiece. Thus a self-sufficient robotic arm is designed and fabricated. This increases their speed of operation and reduces the complexity. It also brings about an increase in productivity. Four degrees of freedom is used in this arm to move along in XYZ directions and also it has some additional sensors.

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Keywords: Stepper Motors, Microcontrollers, End Effector, Finger Gripper

1. Introduction

To reduce the work done by the humans, automation or semi-automation becomes the solution. Here Flexible machining system is the future for the automation in the industries. In this chapter we are going to deal with FMS and its advantages, limitations.

Flexible Manufacturing System(FMS)

FMS will be the future of the industrial automation. A flexible manufacturing system (FMS) is a maufacturing system in which there is some amount of flexibility that allows the system to react in the case of changes, whether predicted or unpredicted. This flexibility is generally considered to fall into two categories, which both contain numerous subcategories. One trend is increased use of machine vision to increase in the use of robots. Industrial automation is simply done at the industrial level. According to Shell (2000) et al. industrial robotics is a sub-branch in the industrial automation that aids in various manufacturing processes.

"Hence, with the help of automation, robotics and other innovative concepts such as just-in-time (JIT), Production planning and control (PPC), enterprise resource planning (ERP) etc., manufacturers are very keen to attain these factors." "Flexible manufacturing is a theory which permits production systems to perform under high modified production needs. The problems such as minimum inventories and market-response time to bump into customer needs, response to adjust as per the deviations in the market.

Robotic arm

A Robot is a virtually intelligent agent capable of carrying out tasks robotically with the help of some supervision. Practically, a robot is basically an electro-mechanical machine that is guided by means of computer and electronic programming. Robots can be classified as autonomous, semiautonomous and remotely controlled. Robots are widely used for variety of tasks such as service stations, cleaning drains, and in tasks that are considered too dangerous to be performed by humans. A robotic arm is a robotic manipulator, usually programmable, with similar functions to a human arm.

This Robotic arm is programmable in nature and it can be manipulated. The robotic arm is also sometimes referred to as anthropomorphic as it is very similar to that of a human hand.

2.Objective and Scope

The main objective of this design and fabrication of ‘ Design and fabrication of robotic arm for FMS’ is to design and fabricate a Robotic arm which could be used to fix the work piece in the CNC machine and remove if once the machining process is completed. Also the arm can be used to fix and remove piece and transfer it to other machines by the application of Flexible machining process.

This gives us a chance to increase production rate and reduce human power. Not only this the FMS can make us perform production without break time with flexibility. Flexible manufacturing is a theory which permits production systems to perform under high modified production needs.

3. Literature Review

Growth of Industrial Automation

In 1745, Jacques de Vaucanson invented the first automated loom. In 1771 Richard Arkwright invented the first fully automated spinning mill driven by water power, known at the time as the water frame. The centrifugal governor, which was invented by Christian Huygens in the seventeenth century helped a lot in the field of automation. The centrifugal governor was also used in the automatic flour mill developed by Oliver Evans in 1785, making it the first completely automated industrial process. The governor was adopted by James Watt for use on a steam engine in 1788 after Watt’s partner Boulton saw one at flour mill Boulton and Watt were building.

The governor received relatively little scientific attention until James Clerk Maxwell published a paper that established the beginning of a theoretical basis for understanding control theory. Relay logic was introduced with factory electrification, which underwent rapid adaption from 1900 through the 1920s. Development of the electronic amplifier during the 1920s, which was important for long distance telephony, required a higher signal to noise ratio, which was solved by negative feedback noise cancellation. This and other telephony applications contributed to control theory. Central electric power stations were also undergoing rapid growth and operation of new high pressure boilers, steam turbines and electrical substations created a large demand for instruments and controls. Factory productivity was greatly increased by electrification in the 1920s. Military applications during the Second World War that contributed to and benefited from control theory were fire-control systems and aircraft controls. The word "automation" itself was coined in the 1940s by General Electric.

Automation of material handling

Shell, Richard (2000) wrote valuable information industrial robotics and automation. They said that industrial robotics is a sub-branch in the industrial automation that aids in various manufacturing processes. Such manufacturing processes include;

machining, welding, painting, assembling and material handling. Industrial robots utilize various mechanical, electrical as well as software systems to allow for high precision, accuracy and speed that far exceeds any human performance. Ghazi Abu Taher et al. (2014) published a paper in International Journal of Scientific and Research Publications about automation of material handling using conveyors. Following were inferred from their publication. Belt conveyor and Bucket elevator are the media of transportation of material from one location to another over longer distance in a commercial space. Belt conveyor has huge load carrying capacity, large covering area simplified design, easy maintenance and high reliability of operation. Belt Conveyor system is also used in material transport in foundry shop like supply and distribution of molding sand, molds and removal of waste. This paper was mainly based on the combination of Belt and Bucket Conveyers to perform complex task within a short time and successfully in a cost-effective way. On account of this, a machine and its physical description is covered here with some basic calculation. They used a conveyor belt (or belt conveyor) that consists of two or more pulleys, with a continuous loop of material - the conveyor belt - that rotates about them. Conveyors are durable and reliable components used in automated distribution and warehousing. In combination with computer controlled pallet handling equipment this allows for more efficient retail, wholesale, and manufacturing distribution. It is considered a labour saving system that allows large volumes to move rapidly through a process, allowing companies to ship or receive higher volumes with smaller storage space and with less labour expense.

Robotics for FMS

When most engineers think about “flexibility,” they imagine robots. Because of programmable controls, end-of-arm tooling and machine vision systems, the devices can perform a wide variety of repeatable tasks. “Robotics is a key component of flexible manufacturing,” claims Ted Wodoslawsky, vice president of marketing at ABB Robotics Inc. (Auburn Hills, MI). “Any applications that involve high-mix, high-volume assembly require flexible automation. Manufacturers need the ability to run different products on the same line. That’s much more difficult to do with hard automation.”

The automotive industry is still considered to be the role model for robotic flexibility. However, Wodoslawsky says many of the lessons learned by automakers and suppliers can easily be applied to other industries and processes. “Automotive manufacturers are faced with producing a greater mix of vehicles in a shrinking number of plants,” adds Walter Saxe, automotive business development manager at Applied Robotics Inc. (Glenville, NY). “This practice is driving the need for higher payloads, faster tool changeover and greater control of data to achieve maximum flexibility and exacting production details. This in turn is challenging the makers of robots and tools to stay ahead of the ever-increasing market. For instance, state-of-the-art robots feature force control, which offers an extra degree of flexibility for critical applications such as powertrain assembly. Other new tools and features that make robots more suitable for flexible production applications include open architecture that allows easy integration with commonly used PLC platforms and offline simulation from desktop computers.

“Manufacturing engineers should ensure their controls platform has the ability to manage, manipulate and store all the data that is required with flexible implementation schemes,” says David Huffstetler, market manager at Staubli Robotics (Duncan, SC). “It can become a critical issue in places where you least expect it to happen. According to Huffstetler, networking, continued standardization in protocols, and enhanced predictive maintenance tools, in addition to transparency and openness in software capability, will make future generation of robots even more flexible than they already are. “Having robotic mechanics in place that can be quickly reprogrammed, along with the minimal retooling effort of only product-critical pieces is what flexible automation is all about,” he explains.

However, when it comes to true flexibility, or the ability to move quickly from job to job, robots are still not as flexible as humans. The biggest culprit is ease of programming, claims Efi Lebel, CEO of SmartTCP Inc. (Farmington Hills, MI). “Programming time is typically very long, even for a one-minute operation,” he explains. For instance, to accomplish one hour of robotic welding, Lebel says it usually takes 15 to 20 hours of programming. “Robots are built to be flexible, but programming is difficult and time-consuming,” adds Lebel, who has developed software that allows robots to be more flexible. “With our product, it can take minutes to hours, rather than hours to days, to program tasks, depending on the application.” The software automates complex and tedious robot programming.

Origin of industrial robots

An industrial robot is a robot system used for manufacturing. Industrial robots are automated, programmable and capable of movement on two or more axes. Typical applications of robots include welding, painting, assembly, pick and place for printed circuit boards, packaging and labeling, palletizing, product inspection, and testing; all accomplished with high endurance, speed, and precision. They can help in material handling and provide interfaces. In the year 2015, an estimated 1.63 million industrial robots were in operation worldwide according to International Federation of Robotics.

The earliest known industrial robot, conforming to the ISO definition was completed by "Bill" Griffith P. Taylor in 1937 and published in Meccano Magazine, March 1938. The crane-like device was built almost entirely using Meccano parts, and powered by a single electric motor. Five axes of movement were possible, including grab and grab rotation. Automation was achieved using punched paper tape to energise solenoids, which would facilitate the movement of the crane's control levers. The robot could stack wooden blocks in pre-programmed patterns. The number of motor revolutions required for each desired movement was first plotted on graph paper. This information was then transferred to the paper tape, which was also driven by the robot's single motor. Chris Shute built a complete replica of the robot in 1997.

George Devol applied for the first robotics patents in 1954 (granted in 1961). The first company to produce a robot was Unimation, founded by Devol and Joseph F. Engelberger in 1956. Unimation robots were also called programmable transfer machines since their main use at first was to transfer objects from one point to another, less than a dozen feet or so apart. They used hydraulic actuators and were programmed in joint coordinates, i.e. the angles of the various joints were stored during a teaching phase and replayed in operation. They were accurate to within 1/10,000 of an inch[citation needed] (note: although accuracy is not an appropriate measure for robots, usually evaluated in terms of repeatability - see later). Unimation later licensed their technology to Kawasaki Heavy Industries and GKN, manufacturing Unimates in Japan and England respectively. For some time Unimation's only competitor was Cincinnati Milacron Inc. of Ohio. This changed radically in the late 1970s when several big Japanese conglomerates began producing similar industrial robots.

4. Conceptual design

The design was based at kinematic linkages and mechanisms. Hence it is designed with space occupation and then implemented. The conceptual design for robotic arm for FMS is done in 3D drawing using solidworks 2016. The 3D drawing is shown in fig 4.1.

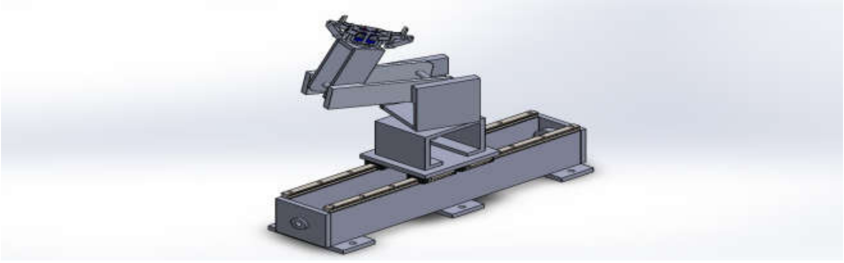


Fig.4.1 3D model of robotic arm

Components

The robotic arm with its various components working operation is been explained below. The 2D and 3D diagrams were also shown in fig 4.2 and the working calculations for these parts are detailed.

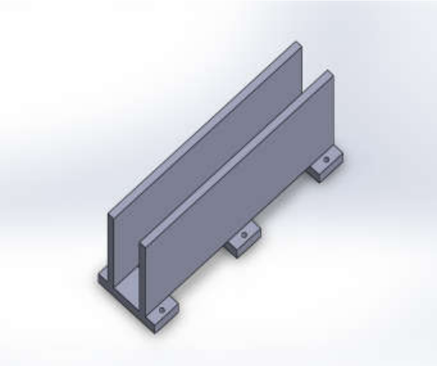


Fig 4.2 a.Base

Fig.4.2 b. Rail

Fig. 4.2 c. Rail block

Fig. 4.2 d. Ball screw

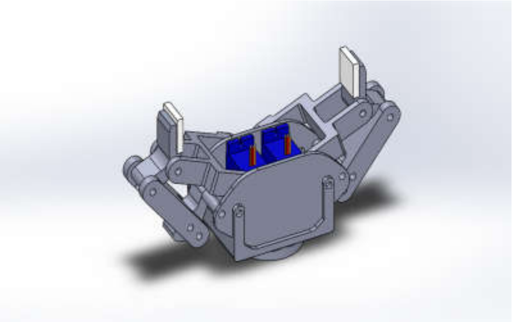


Fig. 4.2 e. Gripper

Fig. 4.2 f. Stepper motor

DESIGN CALCULATION

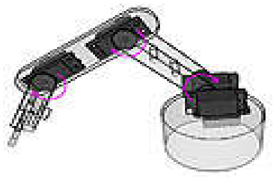


Fig. 4.3 Assembled Arm

Torque (**T**) is defined as a turning or twisting "force" and is calculated using the following relation:

$$T = F*L$$

The force (**F**) acts at a length (**L**) from a pivot point. In a vertical plane, the force acting on an object (causing it to fall) is the acceleration due to gravity (**g** = 9.81m/s^2) multiplied by its mass:

$$F = m*g$$

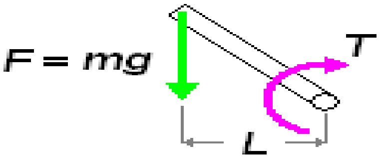
The force above is also considered the object's weight (**W**).

$$W = m*g$$

The torque required to hold a mass at a given distance from a pivot is therefore:

$$T-(m*g)*L$$

This can be found similarly by doing a torque balance about a point. Note that the length L is the **PERPENDICULAR** length from the pivot to the force.

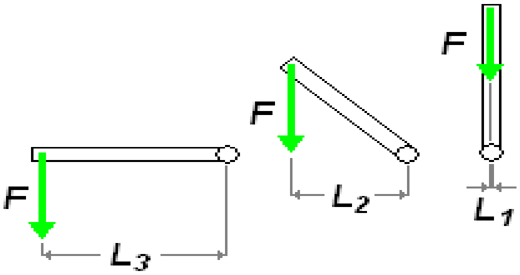


$$\sum T = 0 = F*L - T$$

Therefore, replacing F with m*g, we find the same equation above. This method is the more accurate way to find torque (using a torque balance).

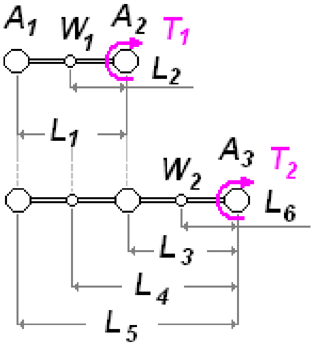
$$m*g*L = T_A$$

In order to estimate the torque required at each joint, we must choose the worst case scenario.



:

$$T1 = L1 * A1 + \frac{1}{2} L1 * W1$$



$$T2 = L5 * A1 + L4 * W1 + L3 * A2 + L6 * W2$$

$$T2 = (L1 + L3) * A1 + (\frac{1}{2} L1 + L3) * W1$$

$$+ (L3) * A2 + (\frac{1}{2} L3) * W2$$

$$T = I * \alpha$$

$$I = \frac{m * r^2}{2}$$

$$I_N = \sum_{i=1}^{N-1} \frac{m_i r_i^2}{2}$$

$$\sum T_N = T_N(holding) + T_N(motion) = I * \alpha$$

Torque **= (P X 60) / (2 X 3.14 X N)**
= (100 X 60) / (2 X 3.14 X 100)
= 9.554 Nm
= 9.554 x 10^3 Nmm

The shaft is made of MS and its allowable shear stress = 42 MPa

Torque **= 3.14 x fs x d ^{3} / 16**
9.554 x 10 = 3.14 x 42 x d ^{3} / 16
D = 10.50 mm

The nearest standard size is d = 11 mm.

Cutting speed

Inputs

N = 100 rpm

D = 25 cm

Solutions

Linear velocity

V = (pi*d*N)/60

V = (3.14*0.25*100)/60

= 1.3083 m/s

Force acting

F = (m*(V-U))/T

For mass

= 0.12 kg, U=0, T=1s

= (0.12*(1.3083-0))/1

F = 0.1569 N/kgs

Conclusion :

The goal of less or no probability of error; with real time management is achieved. Easy operating format by use of computer is obtained. Elimination of the stressed watch by human operators on systematic working to achieve desired production in the industry is made. A solution for the simultaneous accomplishment of assembling work done in the industries by the means of single computes has not only provided ease in operation but also provides autocratic nature for monitoring purposes is designed.

This project is made with pre planning, that it provides flexibility in operation. This innovation has made the more desirable and economical. It was designed with the hope that it is very much help full to mechanical fields. Thus we have completed the project successfully.

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