Case Study of Automation for Duplex Grinding Machine

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Abstract: **The article explores the concept of Robotic arm for automation, the technologies which are used for Robotic arm automation, application of low cost automation. Solution for repeated pick and place type of job, basic components of robotic arm .The ongoing work in automating the feeding of components to duplex or double grinding machine, methods by which cost cutting can be done in Manufacturing of Robotic arm. The design and manufacturing of simple robotic arm is introduced in this article. Autonomous robotic arm can be used for enhancing safety, performance and control in the manufacturing industry. Additive manufacturing methods can be useful for manufacturing parts of robotic arm. Numbers of benefits are discussed about applying additive manufacturing methods for manufacturing parts for variety of robotic arms.**

Keywords: **Autonomous robotic arm; Additive manufacturing (AM) in robotics; Automation in double grinding machine; use of cloud based systems in Robotics.**

I. INTRODUCTION

Automation can be defined as the technology by which a process or procedure is performed without human assistance. Automation is achieved by many ways like mechanical, hydraulic, pneumatic, electrical or electronic devices and computers usually used in combined state. The advantages of using automation is cost cutting in terms of labors, improvement in material handling, improvement in quality , accuracy and precision.

Low cost automation is a technology that creates some degree of automation around the existing equipment's, tools, methods and people, using mostly standard components available in the market. In small scale industries usually in machine shops such type of automations are used, also where less expenditure is expected to invest in automation this type of low cost automation is used.

In less precision works like pick and place jobs low cost automation is used in form of Robotic arm. [1] It is generally programmed for performing a typical type of function. The links of such manipulator are connected by joints allowing either rotational or translational (linear) motion. [2]

In many SMEs (Small and Medium Entrepreneurs) there are problems which require solution with as much as less cost. SMEs can use automation solution for many problems so that their productivity can be increased. The main challenge is to build such automation solution at lower price. Also in industry the problem of safety for operator is major issue this must be overcome.

Robotic arm can be used for performing many times of jobs .But generally used for picking a job from one place and then placing on required position is done by using robotic arm.

In low cost automation using Robotic arm is generally done using stepper motor and related work is also going on to make it more accurate and cost efficient. ST Robotics offers a number of stepper-driven robotic arms, which have sub-mm repeatability. Robotic arm are made by using parts like motors, processors, actuating links, sensors and some mechanical parts such as gears, gripper etc.

A. Controller:

Processors perform as brain of whole system. There are various processors used according to requirements of job. Many times Arduino is used due to its compatibility for different manipulator's work.

B. Motors :

Motors are the actuators of the robotic arm Servo motor is most famous for use but in large load conditions stepper motor is used. According to working conditions and need of accuracy of angular position brushless DC motors and other types can also be used.

C. Actuating links and mechanical parts :

The load which is to be lifted and working environment are the factors responsible for designing of the links. The load coming on the arm, movement, different stresses are the governing factors in case of designing and select material for the links and gripper.

D. Sensing element:

Sensors are the input devices which gives real world condition to the robotic arm system. Generally proximity sensor is used in pick and place robotic arm to ensuring of picking of product, in some cases ultrasonic sensors also used with some attachments.

E. Communicating devices:

For transmitting the data from robotic arm to any other machine or to central system there is need of communicating system or module. While performing for large size of data or for the more number of devices Wi-Fi module is best suitable, but in case only between two systems the data is required to be transmitted Bluetooth module can be used.

As automation will help in many ways for increasing profit of firm as it has several advantages over non automated or conventional methods. These benefits are given in Table 1.

Sr. No.	Automation	Conventional Method
1.	Shorter cycle time	Larger cycle time
2.	Improved Quality and Reliability	Skilled workers are required for quality.
3.	Increased safety	Due to working environment many time harmful for operators
4.	Reduced waste	Due to errors many times material is rejected.
5.	Better floor utilization	As use of shop Floor control techniques will not be effectively used.
6.	Attract more customers	No effect on customers.
7.	Expert at multiple application	As expatriation is depends upon skill of labor hence limited expertise.
8.	Ease in adapting computer integrated manufacturing techniques.	As CIM techniques are more useful for productivity but cannot be effectively used for manual operations.
9.	Detailed list of operation and shop floor can easily transferred to top management	Oral and written communication is generally methods used on shop floor, hence are not generally reach up to top level management.

Table 1: automation and Conventional method comparison

II. LITERATURE REVIEW

There are a number of robotic arms used in robotics research today, many with unique features and design criteria.

In this section, we discuss some recent widely-used and/or influential robotic arms.

The Barrett WAM is a robot which is cabled and has great driveability. Also this robot moves smoothly with fast operation. The speed at which this can perform is up to 3 m/s also have a nice repeatability rate of 2mm.[3]

Series elastic is intended for human interaction and many projects and research has been done on this some robots which are made using series elastic are Meka A2 arm[4],Cog[5],Domo[6],Obrero[7],Twenty one[8],Agile Arm.[9] The Meka arm and Twenty-One use harmonic drive gearheads and Cog uses planetary gearboxes, while Domo, Obrero, and the Agile Arm use ball screws for drive; all this uses different mechanisms for their series elasticity. Due to series compliance the robotic arms have less control bandwidth (less than 5 Hz), yet that has not worked as barrier to use in manipulation research.

Some human-safe arms have been developed at Stanford using a macro-mini actuation approach [10], combining a series elastic actuator with a small motor to increase bandwidth [11].

The Robot PR2 [12] has a very special system which uses passive gravity compensation mechanism, so arm float in any configuration. As mass of arm is supported relatively small motors are used to actuate. These small motors gives Human safety, as it is easy to back drive them due to their gear ratio is less. [13]

The DLR-LWR III arm [14], Schunk Lightweight Arm[15], and Robonaut[16] in this they uses motors directly mounted to joints and using harmonic drive gearheads it provides fast motion with almost no backlash. These robotic arm have high payload (range3-14 kg). As they have large flying masses they seems to be less oblique towards human safety, although demonstrations with the DLR-LWR III have been performed that incorporate a distal force/torque sensor that uses the arm's high bandwidth to quickly stop when collisions are detected.

As other Robotic arms cost almost $ 100,000 USD there are some low cost robotic manipulators which are also used in research. The arm on Dynamid robot [17] is constructed from Dynamixel Robotic servos, which is light and compact. This robot works on lower payload of 1kg. It cost almost $3500 USD.

The KUKA YOU BOT[18] arm is 5DOF arm and work in small work space just above $0.5m^3$, also has good repeatability of 0.1 mm, it can work with payload of 0.5kg. It has custom, compact motors and gearheads and it cost nearly 14,000 Euro.

Cloud robotics is mainly aiming at transferring the highly complex computing process to cloud platform through communication between the robots or machines and cloud system. In this the computing data is uploaded to the cloud and hence the computing load on the machine or equipment is reduced. Also use of big data for robotics will access the system to massive resources like pictures, maps, and object data from the global. With open source the data and codes and other information can be available so ease for development of new technology. The robots cooperative learning the individual robots shortcoming can be overcome by others to increase the overall performance and accuracy. The networking in the robots and machines and cloud may be direct or indirect is possible with use of wireless networking. With use of cloud robotics the high performance systems which are required for computing onboard are no longer required so reducing the cost of multi robot systems or overall systems [19].

The technology for industrial development and transformation of industry is based on many things which are integrated. This technology with human as core for interaction between machines will significantly increase the rate of development in industry. To develop intelligent manufacturing and intelligent factories based on CPS (Cyber Physical Systems) hence it is inevitable to use such new technologies to connect to internet, data bases, transforming systems, pickup and place systems, etc. So to do this all the factory must be designed in such way that it works on CPS and IOT (Internet of Things) or Cloud. Also for ease and simplicity of factory using wireless networking is much more important. Automated Guided Vehicles (AGV) is used to improve the transportation and material handling. This will help to develop an industry in which man force can be part and can perform their task from internet also the record of all the systems can be monitored for accurate working and hence as core part of smart factories human and machines will lead industries towards revolution [20].

III. CASE STUDY

Robotic Arm:

This case study is from "KEDAR PRECISION COMPONENT", this industry is specialized in double grinding process. Currently they are facing a problem in terms of safety of labors, human fatigue problems and expenditure related to labors. When components are fed for grinding in duplex machine there is chance of injury to the operator. Also for such simple job minimum pay for labor are not affordable. Hence to overcome this pick and place job a robotic arm is used. We are currently working on this project with the industry.

Now day's industry is very widely using robots and automation solution for repeating and unskilled works. As less precise work requires less investment for providing automation many low cost robotic arms are available in market. Robotics industry is growing very fast and still has a lot of work and research to be done yet. "Industry 4.0" is the upcoming era of industry.

After surveying for automation solution and needs we found that Robots are the future in many jobs, but pick and place type less accurate jobs are going to be done with help of robotic arm. So, to develop the best solution at least cost is the main theme in developing "Autonomous robotic arm".

A. Need and Concept :

Robotic arm available in market are very much costlier in our region due to many facts like Import duty on Robot, on its parts, Les competition, relatively less knowledge to reduce cost, etc.

After visiting some of double grinding machine industries we have found a particular problem of feed jobs into duplex machine as the grinding wheels are running above 3000 rpm it is unsafe to feed the job manually also it requires a person to continuously pick the raw material and place on machines magazine which makes it less productive process. So in order to overcome this difficulty a pick and place robotic arm must be used which will perform both the operation of picking the raw material and feeding it to duplex machine.

Also in many industries for arranging the component in particular order one labor is required which is hectic job and also there are chances of Human fatigue error. In foundry industry for lifting and pouring the molten metals cranes are used but in small scale foundries or in such cases where less quantity is required to pour or when for making correct composition other materials are required to melt, in such cases use of crane is not economical also very difficult if the mold is small. So, Robotic arm can perform such functions economically and also with ease.

In hotel industry for lifting the heavy cans, hot and heavy utilities robotic arm can be used also with providing some attachment can make it possible to serve the dishes to the consumers these are some needs explained by some owners and experts in this industry.

B. Manufacturing process :

There are many ways of manufacturing parts of a robotic arm. But the dimensions of robotic arm many times changes according to the application and its working environment, availability of space. Hence it become more costly if one adapts conventional processes for manufacturing parts of robotic arm. Also the weight of Arm will make systems bulky if conventionally manufactured.

Use of advanced manufacturing processes in developing and manufacturing robotic arm will be beneficial in terms of cost as well as time. There are several techniques which are developed to manufacture single or less quantity of component at less cost. Some examples of techniques for such small batch production or testing components are improving old machine tools with attachments, use of Additive Manufacturing (AM) methods, etc.

Major advantages of using AM techniques are reduction in lead time of manufacturing, reduction in overall cost of manufacturing by prototyping and concept testing. Higher flexibility in manufacturing leads to easier imagination and hence new type of design can be developed. Design failures can be identified in early stage which is preventing major losses in terms of investments, reliability and customer satisfaction.

C. Assembly :

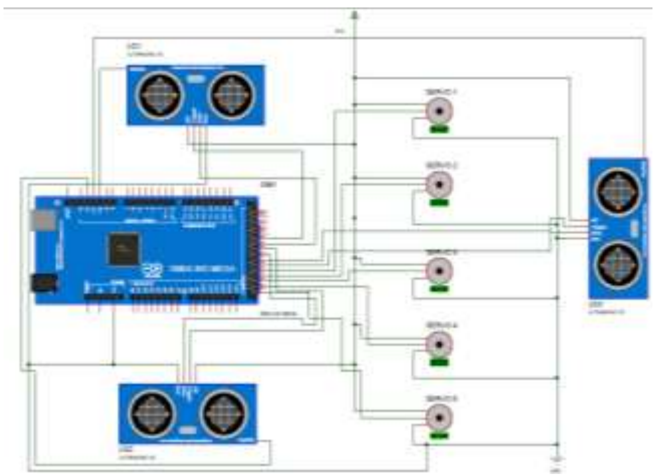
While assembling robotic arm with controller and Bluetooth module it will much helpful if the pins and ports are already decided. As they can be directly used while programming as input and output ports and programming can be done easily.

Also some circuits for power supply are required also use of power source such as SMPS are also recommended as smooth and continuous supply of current is obtained. Also it is better to know how to assemble the shafts with links which are manufactured and how to mount motors and their connections.

D. Circuit :

As there are total 6 number of servo motors and 3 ultrasonic sensor or 2 ultrasonic and 1 proximity sensor and Bluetooth module it is necessary to give power supply from external circuit rather than using arduino supply directly. As arduino is an open source and there are variety of circuits available in market which are known as arduino shields can be directly used and mounted on it and much simple and neat type of system can be build.

Schematic circuit for 5 servo and 3 ultrasonic sensors along with Arduino mega is shown in Figure 1.



E. Algorithms and libraries:

Programming is main thing which is going to control all the operations and making the robot autonomous. As machine learning is going to be much helpful for doing robot self-learning and hence improving same for the decision making.

Arduino IDE is our platform for coding along with following libraries: Servo, Wi-Fi/Bluetooth, Serial.

Step 1: Check for obstacles.

Step 2: Move the motor at base to desired angle

Step 3: Move the motor at above base to desired angle

Step 4: Move the motor 4 to desired angle

Step 5: Move the motor 3 to desired angle

Step 6: Move the motor 2 to desired angle

Step 7: Check for material, if material sensed, Move the motor 1 to desired angle, else move the motor at base until material is sensed, then move motor 1 to desired angle.

Step 8: Move the motor 2 to desired angle

Step 9: Move the motor 3 to desired angle

Step 10: Move the motor 4 to desired angle

Step 11: Move the motor 5 to desired angle

Step 12: Check for obstacles and with sensing for obstacles move the motor 6 to desired angle

Step 13: Move the motor 5 to desired angle

Step 14: Move the motor 4 to desired angle

Step 15: Move the motor 3 to desired angle

Step 16: Move the motor 2 to desired angle

Step 17: Move the motor 1 to desired angle

Step 18: Move the motor 2 to desired angle

Step 19: Move the motor 3 to desired angle

Step 20: Move the motor 4 to desired angle

Step 21: Move the motor 5 to desired angle

Step22: Check for obstacles and with sensing for obstacles move the motor 6 to desired angle

With this algorithms for variety of jobs robotic arm can be programmed. When work is required to be set on priorities that time using Assignment problem of operational research for decision of job or work selection is done.

F. Design and Calculation :

Design part consists of choosing material and finalizing the dimension of links and also calculation of torque of motor.

G. Material selection:

After deciding to manufacture Robotic arm by using 3D printing we studied 3 materials PLA, ABS and Carbon Fiber Composite. As Carbon Fiber has very good strength it is an ideal material which can be used for manufacturing of links but it is also very expensive almost 2.5 times of PLA. ABS is good but due to its tendency of warping after cooling we decided not to select ABS.

PLA has good strength of 46.76MPa in tension and also half in shear also its very much cheaper than Carbon fiber composite. So we decided to Select PLA.

H. Design and calculation:

After deciding manufacturing the links and roller by using the 3D printing we researched about the materials which are used in 3D printer we selected PLA for printing and collected its properties and started to design using their properties:

PLA Properties:

Shear stress: 23.38 N/mm2

Tensile stress: 46.76N/mm2

Factor of safety: 2.5

a) Cross section of the arm:

Now we know for PLA material

Tensile stress = 18 N/mm2

Load on arm = 500gm

Cross section = b×t

TS = P/A

= (0.5×9810)/b×t

B×t = (0.5×9810)/18 ………(taking b=2.5t)

2.5t2 = 272.5

t = 10mm b= 2.5×10 = 25mm

b) Length of the arm:

According to our load capacity and travel distance we assume

L = 160mm

c) Pin hole center distance :

As per our design of pin as diameter 8mm

The center distance = L-b

= 160-25

= 135mm

d) Robot base

We have to design

Thickness of base cap, Diameter of the base, Length of the base, Thickness of the base cap

Considering failure of cap in shear

Shear stress = P/πDt1

P = load on the cap head

D = 8t - - - -(D = internal diameter)

t_2 = (1×9810)/(π×8×9)

t = 6.58mm

Taking t as = 10mm

Diameter of the base cap

D = 8×10= 80mm

Length of the base

L = 110mm

Height of the base cap

For the arrangement of gear train and drive of motor we take

h = 80mm

e) Rotational supporter

We have to design

Width of supporter, Thickness of supporter, Diameter of pin hole, Height of supporter strip, Width of supporter

According to our robotic arm design the strength should be maintained,

So we assume that

Width of supporter strip = 25mm

Thickness of supporter strip= 10mm

Diameter of pin hole

From our design of pin (dp = 8mm)

We require pin hole diameter = 8mm

Height of supporter strip

Height of strip = 30mm

f) Robotic arm pin (shaft of motor) design

Considering failure of pin in share

Shear stress = P/2A - - -- (due to double shear we take 2)

2π/4 ×dp2= P/shear stress

=√((P×4)/(π×shear stress))

= √((0.5×4×9810)/(π×2×40))

dp = 8mm

g) Torque calculations of robotic arm:

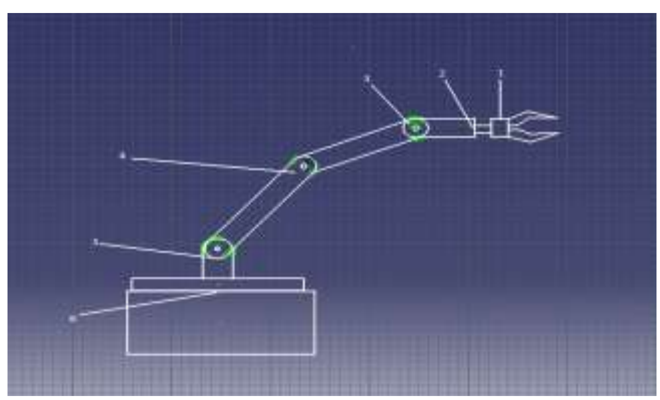


Figure 1: Schematic Diagram of Robotic Arm

Torque at motor 1

T1 = (50×100) + (100×50) = 1kgcm

Torque at motor 2

T2 = (50×105) + (100×55) = 1.1kgcm

Torque at motor 3

T3 = (50×150) + (100×100) + (50×50) = 2kgcm

Torque at motor 4

T4 = (50×310) + (100×260) + (50×210) + (100×160) + (50×80) = 7.2kgcm

Torque at motor 5

T5 = (50×470) + (100×420) + (50×370) + (100×320) + (50×240) + (100×160) + (50×80) = 14.8kgcm

Torque at motor 6

T6 = (50×490) + (100×440) + (50×390) + (100×340) + (50×260) + (100×180) + (50×100) + (50×20) = 15.9kgcm

IV. RESULT AND DISCUSSION

Use of Robotic arm going to improve profit of the firm also beneficial as:

1) Safety for operation enhances due to use of Robotic arm.
2) As feeding is done by Robotic arm labor can be used for some more skilled work.
3) Use of Robotic arm will make automation of material handling economical. As conventionally labors perform the task of material handling which is a hectic job. Also productivity and accuracy due to Human fatigue is limited.
4) Robotic arm can perform same jobs continuously without any fault.
5) Many times robotic arm may give some beneficial from permission point of view in some areas where certain laws are very strict for use of labors.
6) In case if minimum pay for labor is high there use of robotic arm is economical.
7) In case if parts are manufactured by 3D printing will make production for variety of sizes economical.
8) As less human interference in manufacturing the accuracy will be on higher side.
9) According to application many times system without sensor will make Arm cheaper.

The problem of feeding the jobs to Duplex machine is overcome by using this robotic arm. This will ensure accuracy and precision in this job without any error. Also the labor that currently doing this operation can be utilized to perform some other task which will be profitable for industry. Also safety of labors will be ensured by use of this project or Robotic arm. Also we can reduce the overall cost of manufacturing. The cost reduction can be considerable as shown in from Table 2.

	Robotic Arm (in Rs)	Un-skilled labor(in Rs)
Initial Investment	40000	-
Monthly charges	[8*26*11*0.5 =1144]+[200] =1344	Minimum pay scale limit is 7500 Rs.
Yearly cost	-	Bonus 8.33% as per labor law
Maintenance and insurance	Depending on problem	350*12=4200 for ESI scheme
Total for 3 years	88384 + maintenance	2,72,100

Table 2: Cost comparison

V. CONCLUSION

The Robotic arm with capability of thinking about priority of work will make overall work and hence industry much smarter and efficient. Use of machine learning is beneficial in robotic arm for real world experience. Also use of Robotic arm for feeding raw material to the duplex double grinding machine will be much more beneficial for the industry. Use of Robotic arm can reduce the cost of operation up to 60%; also it can be further reduced with time. With cost benefit use of robotic arm will make operation safer, fatigue free, vproductive, and controllable.

VI. FUTURE SCOPE

There is lot of scope for research in this area. Repeatability, cost reduction, ability to take decision, etc. are some of the factors which needed to be researched further for improvement. Use open source material to improve function ability of robotic arm will be appreciable. This will help to reduce the cost of robots. Reduced cost of robots will make them more popular among the SMEs. Ultimately SMEs can develop very rapidly.

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