

# Design of Robotic Arm for Dye Penetration Method/Liquid Testing in Non-Destructive Testing

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**Abstract:** Non- destructive testing (NDT) is a widely used inspection techniques in science and technology industry. NDT is becoming mandatory for industrial inspection mainly for the manufactured components. Basically, Nondestructive methods are performed by humans. There are high chances of getting tiredness while performing the same task repeatedly in manual methods and there are also chances of getting errors. In the industrial sector automation has increasing rapidly and are using for many manufacturing processes. So, integrating non-destructive testing like liquid or die penetration testing, ultrasonic and visual inspection testing with the robotic arm makes the processes fully automation and helps us to achieve precision, accuracy and less time consumption on the inspection of different types of components after the manufacturing processes. Designing a robotic system integrating with visual optics(camera) and liquid penetration system (penetrant, developers, cleaners) allows the inspection fully automatic. It contains dual robotic arm with 6- degrees of freedom, spraying end effector contains liquid penetrant, developer, cleaners.one arm is used to spray the penetrant and developer and another is used to clean the component and to take pictures with visual optics like camera. Camera is used to take the pictures of the component when the defects are visible through penetrant over the developer and sends these pictures to receiver through the transmitter. From this project we have designed the inline robot for the die penetration testing method.

**Keywords:** *Non-destructive testing, automation, Inspection, Degree of freedom, Robot, precision, Accuracy.*

## I. INTRODUCTION

There are many analysis methods in the science and innovation industry to investigate the properties of materials and components. some techniques that can damage the devices and others without causing damage. Non-destructive testing (NDT) is the widely used techniques in the industry helps to find out properties of material and inspecting defects like welding defects etc. [1]. NDT does not cause any damage to the component and saves both money and time in product evaluation, inspection. It plays very crucial role in inspection process in industrial field as it evaluates the producer and consumer risks [2]. The automation of the non-destructive testing increases the quality of the inspection and decreases the unit cost to the industry.as the robots become sophisticated and less expensive effects the range of production volumes over the cost-effective are continuously expanding in the production spectrum.[2].

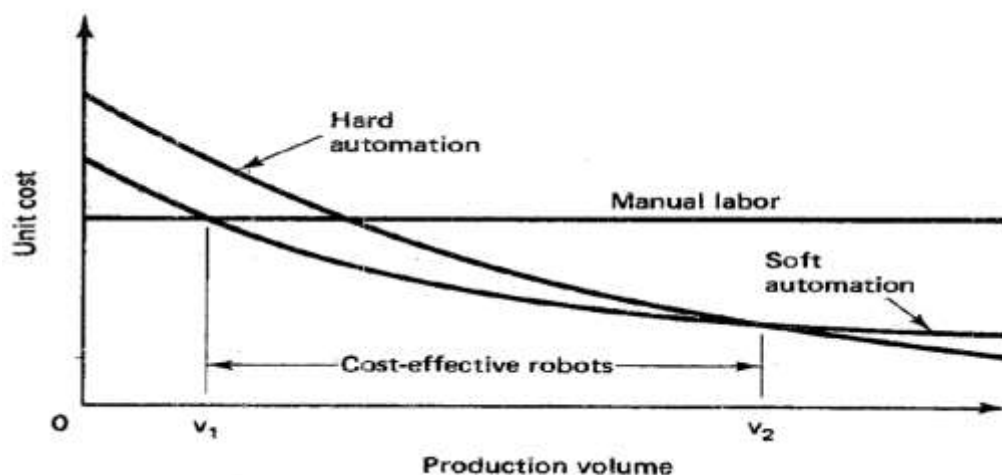


Figure 1. relative cost-effectiveness of soft automation

### Types of NDT:

There are various kinds of NDT techniques or methods

But most commonly used are:

#### 1.Liquid Penetrant Testing:

In this method a liquid (usually with low viscosity) type of material is used to identify the flaws and defects.

#### 2. Magnetic Particle Testing:

In this method magnetic fields are applied to find discontinuities on the surfaces of ferro magnetic materials.

#### 3. Radiographic Testing:

In this method radiations are used to pass through a test piece to identify defects for instance: X-beams and gamma beams are normally utilized relies upon the kind of the material.

#### 4. Infrared Testing:

Also known as thermography, sensors are used to determine the different kinds of wavelengths of infrared light transmitted from the surface, which can be utilized to decide its condition.

#### 5. Ultrasonic testing:

It uses high frequency sound waves which are passable through the material find the flaws like internal cracks or surface cracks and display them on receiver.

These are further classified into different types and used according to their requirements.

#### 6. Visual testing:

In simple terms, manual method Using with magnifying glasses or any other optical instruments to finding surface cracks by an operator.

#### 7. Ground Penetrating Radar testing:

In this method radar pulses are used to find the internal flaws of an object.

#### 8. Laser Testing Methods:

In this method lasers are used to detect the discontinuities

In the object and this method are further classified into three types those are holographic testing, laser profilometry.

#### 1.1. Idea:

To Automate all the non-destructive testing methods with the help of a robot. [future]

Present idea: To automate the dye penetration testing one of the non-destructive methods with the help of a robot.

#### 1.2. Scope of Implementation:

1.this idea allows the inspection process to achieve accuracy, speed, repeatability.

2.this automated robot inspection method helps in high rates of reliability in the inspection process

## 2.Mechanical Design considerations:

The mechanical design of the collaborative robot which can be used to automate non-destructive testing has specifications and parameters to consider. The elements include the functionality of the robot, reliability, motion range, speed, payload capacity, reach and axis are discussed.

**2.1. Functionality:** the function of this robot is to fulfill the dye penetration testing process completely. The two arms function with each other to achieve this. One arm function is to spray the component entirely with penetrant and developer with dwell time and the other arm inspect the defects with the visual inspection camera and sends the data to process. The entire function of the robot is to mimics the whole human dye penetration testing process with addition to accuracy, speed, repeatability in the testing.

#### 2.2. Reliability:

the robot should perform dye penetration test continuously and it should be fully automated. It has to spray both penetrant and developer all-over the surface of the object within the dwell time it has to give the data to the inspection team. The machine should perform consistently then only it will be reliable. the design of the robot achieved this reliability to automate the non-destructive testing that helps to increase the inspection speed and reduces the both consumer risks and producer risks. Also, in industry there is no inline robot in the inspection department to perform the non-destructive methods that can automate the process. With the techniques and data, we can automate desired method to the inspection process.

**2.3. Motion range and speed:** The scope of the automated arm movement is frequently characterized by Levels of Opportunity. In mechanical designing, DOF is the quantity of boundaries expected to characterize some article's setup. More DOF implies greater adaptability, and unavoidably more unpredictable arm plan and programming Each mechanical arm is constrained by working framework running on an advanced PC. The PC will control the automated arm in like manner to its programming. In any case, this is the vital piece of the modern automated arm. Without the working framework and controlling module, a mechanical arm is unequipped for being wise and computerized. For every particular movement, the arm must be planned cautiously, with just capacity of doing one bunch of movement. Nonetheless, with advanced programming, the automated arm can utilize its bit of leeway of adaptability and perform undertakings as requested. To play out its activity, the mechanical robot can work simply under the order of working framework. Additionally, labor can be utilized to painstakingly and precisely manage the arm through a pattern of undertaking, permitting the PC to remember the activity and rehash such activities.

1. Axis rotation base, working range will be (+/-)175 deg and maximum speed will be 150deg/sec and max joint moments 207Nm.
2. Axis rotation shoulder working range will be (+/-)175deg and maximum speed will be 150deg/sec and max joint moments 207Nm.
3. Axis rotation elbow working range will be (+/-)175deg and maximum speed will be 150deg/sec and max joint moments will be 207Nm.

4. Axis wrist rotation working range will be (+/-)175deg and maximum speed will be 180deg/sec and max joint moments will be 34Nm.
5. Axis wrist spring working range will be (+/-)175deg and maximum speed will be 180deg/sec and max joint moments will be 34Nm.
6. Axis wrist rotation working range will be (+/-)175deg and maximum speed will be 180deg/sec and max joint moments will be 34Nm.

#### 2.4. Payload:

A technology that can make life simpler and more convenient is the robot. This robot can perform a wide variety of tasks and helps to reduce operational cost and improve efficiency and the limited weight of each robot is its payload. And it can payload up to 5kg and the weight is 24 kg and footprint is 172mm diameter.

Reach:

In our enunciated robot, we have to check the two limits that is only they-reach and H-reach.

- V-Reach-

A robot's vertical arrives at particular alludes to the stature of the robot when it broadens upwards from the base and the working reach will be 880 mm.

- H-Reach-

The even arrive at measures the separation of the completely broadened arm from the base of the wrist and the working reach will be 924 mm.

#### 2.5. Axes:

The particular fragments of our robot are related with mechanical joints, that serves as an axis of movement. We have designed the robot with 6-axis of movement.

- Axis rotation base
- Axis rotation shoulder
- Axis rotation elbow
- Axis wrist rotation
- Axis wrist swing
- Axis wrist rotation

#### 3. Materials:

The choice of materials will affect its safety, durability, and even aesthetics. Any design project should include considerations of how a robot will move, whether it will operate around people, what tasks it will perform, and the anticipated environment. The materials in this Robert is Steel, aluminum, plastic. Steel is often used in robot manufacturing. This material is very smart choice for robot builders because that need to standup for difficult situations. We can harden the steel to between 100,000 and 300,000 pound-force per square inch (psi) according to the applications. Aluminum is also a good material if you're worried about a robot's exterior becoming rusty over time because aluminum does not rust. Although aluminum has a higher price point than steel, it's easier to shape and is lighter. Another thing that makes aluminum a popular option for robot exteriors is that it can be polished to a high shine. Soft plastic is mostly used to finish up with greater outlook. it comes up with a great touch for robots.

#### 4. PART DESIGN:

The following section discusses the design of the robotic arm with detailed dimensions

#### 4.1. Base and Frame:

This part is the assemble of two parts one is base part and other is the frame of the robot that facilitates the robotic arms collaboration. Base part is of the shape of rectangle which gives balance to the robot. this part is fixed to the ground in the working area with the help of nut and bolt. The fixation of the base helps the robot balance and avoids instability during working process. The body of the robot is a simple and balanced structure that holds the two robotic arms and allows them to collaborate each other to complete the given working process. The base part is the fixed in mechanism and the frame of the robot mechanism is rotational to the y-axis. This rotational mechanism helps to achieve the maximum reach and flexibility to the robot (figure 2).

Dimensions of this part is:

- 1.the length and width of the base is [40,40]cm
- 2.the height of the robotic frame is 90cm
- 3.length of the robotic frame is 100cm
- 4.radius of the robotic frame is 10cm

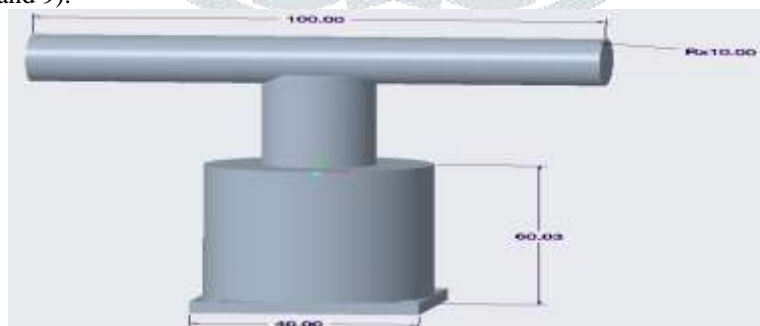
#### 4.2. Robotic arm:

This part is the human arm representation of the robot.it is the assembly of four parts. like human arm it has shoulder, elbow, wrist which has their own function. This robotic arm helps to perform the required die penetration process, all the parts assemble to get a required output. from shoulder to the End-factor wrist each part has the separate rotational moments that gives the robotic arm reach and axis moment. It maintains the strength and flexibility to hold the End-factor to perform the task. This hole assembly is connected to part 1(base) that holds and balances the robotic arm. this this robot design two arms are used to perform the job so art-2 is used twice in the design to represent right and left arms of the robotic mimicking the human arms. The dimensions are given below, assembly details and limitations are discussed in the assembly part (figure 3).

**4.3. End-effectors:** In this part-3 this design part of robotic end-factors is discussed. In this robot there are two end-effectors both has their individual function. Both are assembled to each of the arms on the left arm endfactor-1 is the combination to two spray guns mainly designed for the die penetration process to perform the two functions of spraying penetrant and developer and the endfactor-2 is combination of inspection camera and water shower that helps to resign, clean the part and performs the inspection with the help of camera and send the data to the receiver (refer figure 4 and 5). The dimensions are given in the figures 6.

#### 4.4. Assembly:

The whole part1, part2, part3 mentioned in the design are the pre-assembled parts which are designed individually in Creo - parametric 5.0. after the design of each part first the base is assembled with rotational mechanism of the body next the arm is assembled each part in figure 7. The shoulder, wrist is assembled with the rotational moment along the axis, mechanism is explained in the detail below. These rotational moments help to achieve both horizontal and vertical reach to the robot. The finial and most important parts of the robot are End-factors. only to the spray gums rotational mechanism is given to increase the reach and shift penetrant to developer. The other is fixed to the robotic arm. Each and every mechanism is given to achieve the die penetration inspection process (figure 8 and 9).



**Figure 2.** Base and Body of the Robot



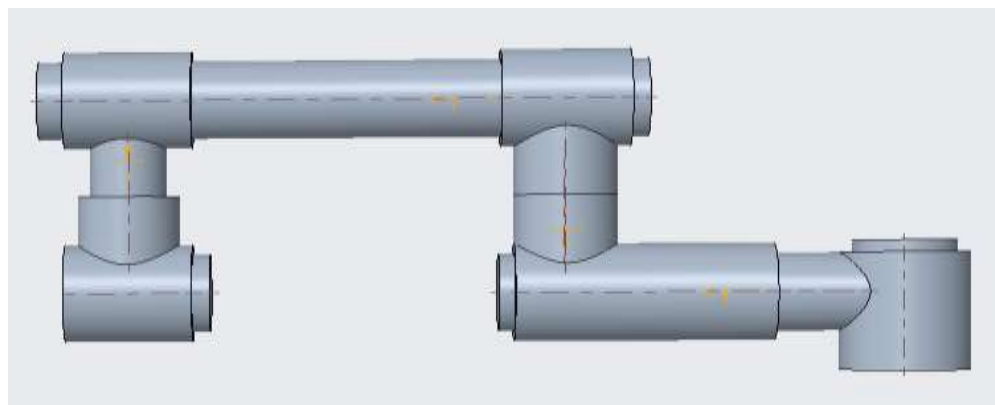


Figure 3. Robotic Arm

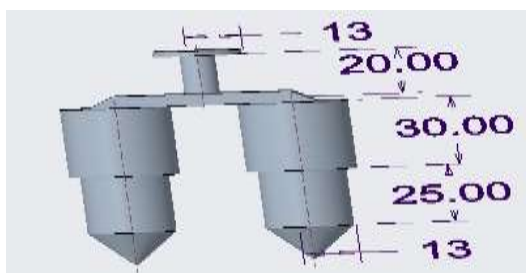


Figure 4. Spray guns-End effector 1

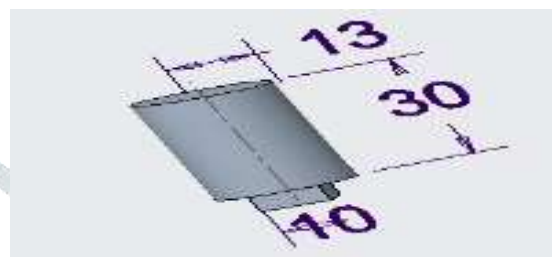


Figure 5. Water shower and inspection camera End-effector 2

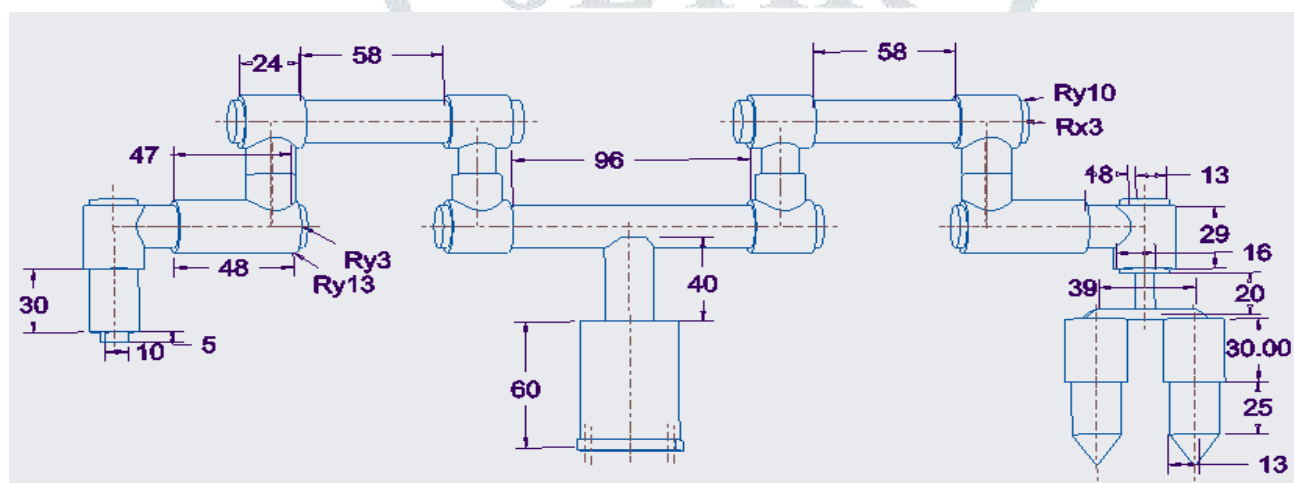


Figure 6. Dimensions of the robot

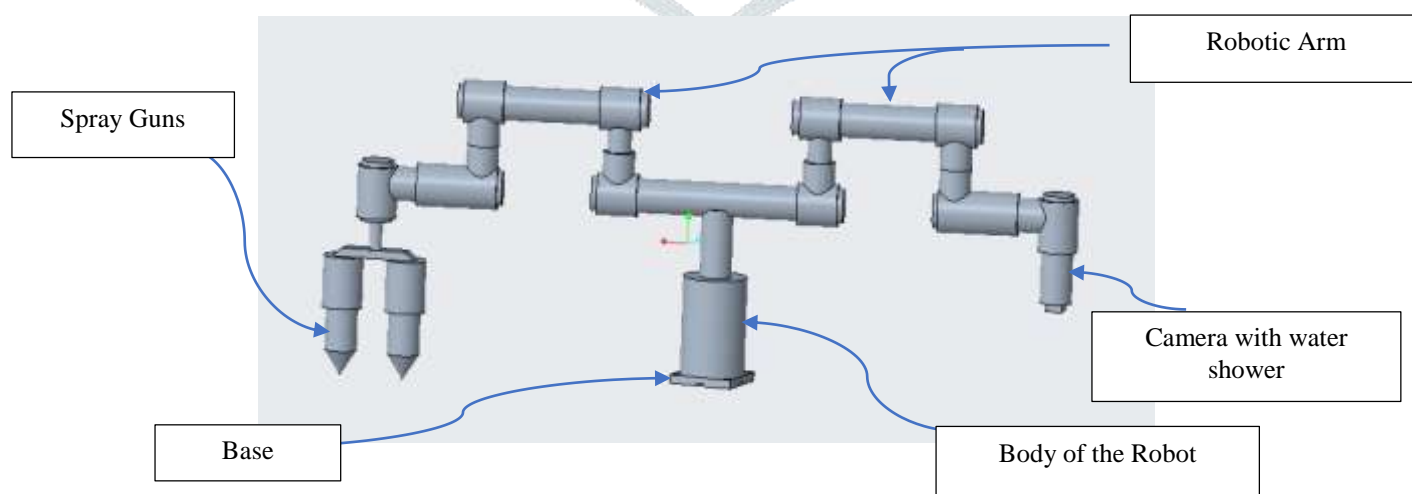
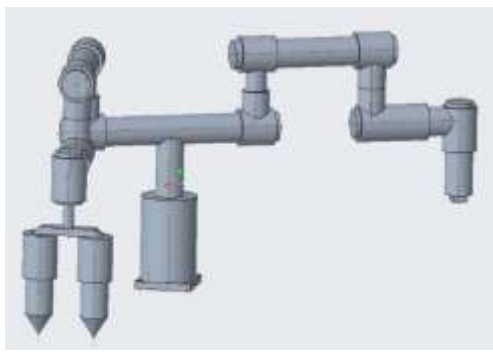
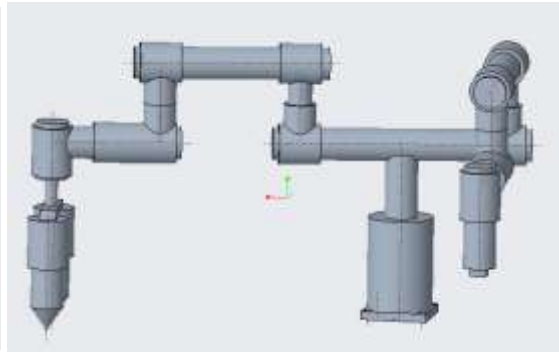


Figure 7. Components of the proposed robotic design



**Figure 8.** orientation of spray guns



**Figure 9.** orientation of inspection camera

## 5. Embedment of Electronic Components

**5.1. Servo motor:** In the robotic eight servo motors are used for the mechanism with four servos in each arm. Servo motors are mounted on a joint of robotic arm and two robotic arm we are using DC Servo motor because it has high torque. Helps in the moment of the robotic joints and achieve the required the moment to perform the tasks. Servomotor allow for near perfect repeatability of motion.

### 5.2. Sensors

#### 5.2.1. Proximity sensor:

Without any physical contact nearby objects are sensed and detected by the proximity sensor. The transmitter sends electromagnetic radiation in the contiguous sensor and gets and investigations the interference input signal. Thus, the light detected in the areas sensors the presence of nearby objects. The sensors advise and sends the collision error methods for the robot to detect the collision before occurrence. There are different sorts of proximity sensors, and a couple of them are typically utilized in robots. [4]

**5.2.2. Infrared (IR) transceiver:** An IR LED transmitter communicate an IR light that reflects the light caught by an IR collector when an item is found in the path.

**5.2.3. Ultrasound Sensor:** This type of sensors transmits and generate sound waves at high frequencies and receives the echo's that detects the presence of objects. Ultrasound sensors can also be used for distance measurement.

**5.2.4. Photoresistor:** It is a light sensor, but it can be used as a proximity sensor. If any item is sensed that changes the lights in sensor, by this resistance is generated and that change helps to detect the object.

**5.2.5. Light sensors:** The function of light sensor is to detect the light and creates the voltage difference. A robot's vision for review has a PC controlled camera that permits the robot to see and change the focus as needs be. The two essential light sensors in robots are Photoresistor and Photovoltaic cells. Other light sensors like phototubes, phototransistors, CCDs, and so on are once in a while utilized [5].

**a) A photoresistor:** I these sensors the resistance is varies when the light intensity changes when intensity increases the resistances increases vice versa.

**b) Photovoltaic cells:** It convert solar radiation into electricity. In this voltage varies when light varies that helps in the light sensing.

**c) 2D & 3D Vision:** 2D vision senses the measure of length and width of any object by image vision. 3D vision allows a robot to detect the orientation and effectively handles the object even the location and position changes. A 3D vision framework can precisely manage a mechanical arm during gathering or examination measure, while an automated arm can give numerous survey points to basic get together assessment to play out the work.

**5.2.6. Acceleration sensor:** This type of sensor detects and measures the acceleration and inclination. The forces that affect accelerometer are: a) Static Force: it is the frictional power between the objects by estimating this we can decide how much robot inclines. This estimation is valuable in adjusting robot and decides the security of the robot [4] b) Dynamic Force: the measure of dynamic force helps to find the speed/velocity of the robot during any working process.

**5.2.7. Liquid sensors:** These sensors have the functions to detect the liquid level in the tank and detects leaks and bubbles in the pipes. These sensors can detect the speed of the liquid in the pipes. in the spraying process these senses the speed and level of the die in the tank [5].

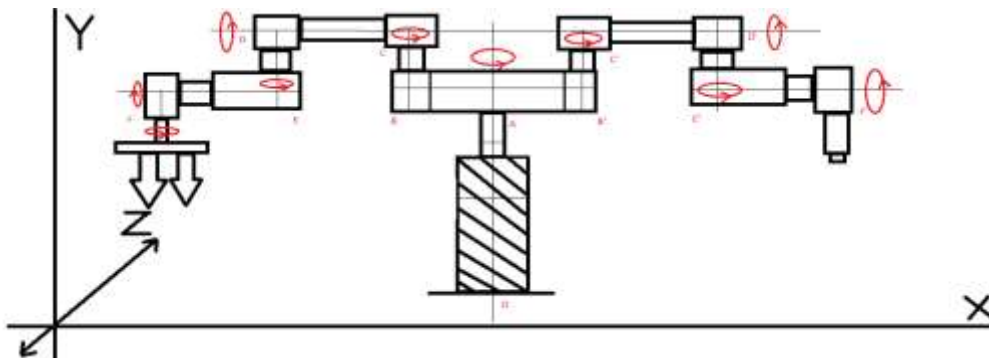
### 5.3. micro controllers

Raspberry Pi and Arduino are the two microcontrollers used as the processor core in the machinery. these helps to perform the embedded applications in the robot. these microcontrollers act as the bridge of communication between all the actuators and sensors and other electronic components.

### 5.4. Core power distribution module

This system distributes the power accordingly to the actuators, sensors, microcontrollers as they vary from one another.

## 6. Mechanism



**Figure 10.** mechanism of the Robot- Front view

The Figure 10 shows the joint B & B' are fixed and joint C & C' through the y-axis. joint D & D' are rotated through x-axis. E & E' are rotated through the y-axis. joint F & F' are rotated through x-axis.

When the component which have to be tested is placed in front of the dual robotic arm at O as in the diagram, then joint C rotates through y-axis then end effector F will be travelled over the component and it will perform its task by spraying die penetrant and that penetrant will take time to fill the pores on the surface of the component and then the same arm which will spray developer over the component and then the defected areas are clearly visible. Then joint C' rotates through y-axis then end effector F' which is integrated with a cleaning liquid sprayer tank and also a camera is placed over the tube will be travelled over the component and camera will takes the pictures of the component's surface and sends to receiver's screen through transmitter and then the arm will clean the die which is previously coated on the component's surface with the cleaning liquid sprayer.

## 7. Conclusion

NDT is an important process in industries to check whether the component is defective or not. Mostly these NDT methods are performed by the humans. The probability of getting errors is high when these processes are continuously performed by human due to the fatigue and tiredness. So, we have a thought to make this process easier and simple. Through this project we have automated the process of dye penetration technique in NDT. So, it will save time and effort of a human and also it has better accuracy, precision and repeatability than the manual method done by a human. We have designed a dual robotic arm to make this process even easier. While one arm is used for spraying the dye and developer over the component and another arm is used to clean the component's surface and as well as it is used for inspection purpose. While inspecting the component's surface second arm which is integrated with camera will capture the pictures of the component and sends to the receiver's screen through transmitter. So, it is easier to store our data and we can also command the robot to capture the photos in whatever perspective we want so it will be useful while doing comparison of those photos. This robot is designed in such a way that it can withstand industrial environment and it is more durable.

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