Journal of Engineering Sciences
Vol 11, Issue 4 , April/2020
ISSN NO:0377-9254

A STUDY ON ROBO CYCLE TIME FOR LOADING ROBOT IN PRODUCTION BASED INDUSTRY

[1]VIJAYAGIRI SRIPAL, [2]SAI KUMAR AMDA

[12]Assistant professor
Department of Mechanical engineering
[1]St Martin's Engineering College, Secunderabad-500100, Telangana state, India.
[2]JB institute of engineering and technology, Hyderabad, Telangana state, India

Abstract: In the assembly process, several components are merged into one unit. The method of assembly strongly affects the manufacturing processes as it takes a very long time and expensive operation. Assembly costs can amount to up to 30% of production costs. Instability and change of direction in assembly processes increase manufacturing costs, thus significantly raising the overall cost of the product. The production rate decreases as montage process time increases, so that the appropriate installation sequence is important to minimize assembly time and cost. The parts' sequences and paths shall be determinate in order to achieve assembly with minimum costs and shortest time by means of assembly sequence preparation (ASP). for the given product assembly model. The robotic assembly system is defined as one that uses robots to perform the necessary assembly tasks. This method is one of the most versatile assembly systems for the assembly of different components. This paper is based on the cycle time analysis for the assembly of the gripper robot from small robot arms.
Key words: Advanced manufacturing systems, robotics, design, critical time analysis

1.0 Introduction

Robots are not a new concept, but are in operation for more also a century in different forms, in order to automate tasks and to reduce the burden for man. But we eventually were able to make this dream come true. In order to simplify, speed up and improve the manufacturing of different products, many companies are already using a range of robotic technologies. Robots are tireless, reliable and effective staff with much more than anything that relies directly on human senses and efforts. They can also work in much harder conditions than humans, especially in dangerous contexts such as nuclear plants, oil plants, mining facilities and so on. The improved level of accuracy in fields like medicine is also a big aid. The creativity and execution of worlds is increasingly possible where human beings take on solely supervisory, management and imaginative functions, while robotic machinery is used as all heavy lifts.

1.1 Objectives of the work

The goal of the present research is to determine, stable, feasible, and optimal robotic assembly sequence fulfilling the assembly constraints with minimum assembly cost. The present work aims is at developing an approach for producing robotic assembly sequences using the evolutionary technique thinking of the degree of freedom, instability of assembly motions and directions. The ultimate goal of the study is as follows.

To generate feasible assembly sequences automatically.

To reduce the cost and time of assembly

To apply new methodologies and modify some conventional methodologies for determining optimal assembly sequences for robotic assembly systems in an orderly manner.

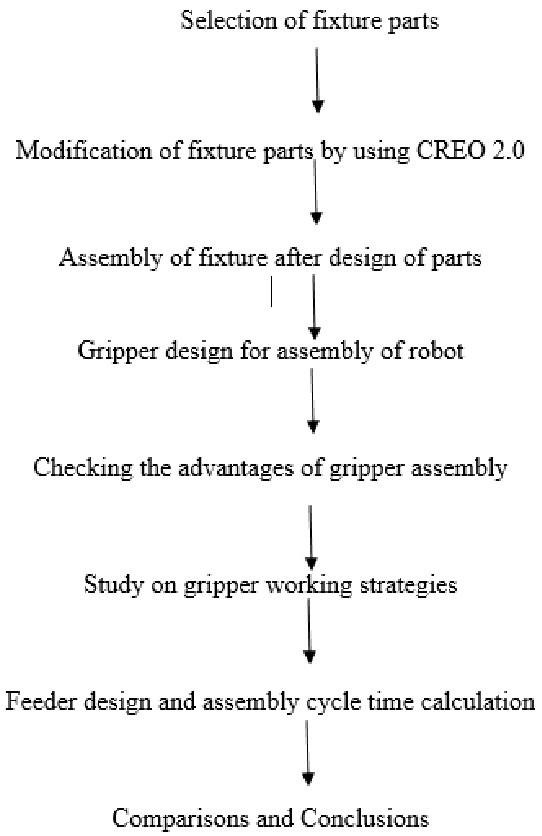
2.0 Literature review

Akturk et al. (2005) This has shown that the cell effectiveness can be enhanced if we consider assigning operations to machines as decision variables. Supposing operation assignment choices are pre-determined on each machine unnecessarily restricts the number of alternatives and overlooks the flexibility of CNC machines. In addition, the following basic feasibility assumes are made by Crama et al. (2000), (1) the robot can not charge an already loaded equipment. (2) The robot could not unload a computer that has already been unloaded. Lei and Wang use a branch and related search process for early work on interval robotic cells.. Ethiopian et al. To find optimum one-unit rounds, using branch and bound, linear, and bi-assessed graphs, and Che et al. use these methods to find the optimally multiunit rounds. Kats et al. solve this issue by using an approach similar to the one used in non-wait cells by Levner et al. Crama shows the confusion effects of such a program.

Vol 11, Issue 4 , April/2020

ISSN NO:0377-9254

3.0 Methodology of work



In the original specification, the plate's diameter and thickness have been specified and the dimensions of the two holes given as 5 mm. Since these two holes are intended for bolts to pass through, the thickness should be the same as or slightly larger than that of the bolts. Using exactly the same thickness will not allow the bolts to directly slide through the holes; instead the holes will need to have pitch and the bolts will need to be screwed in. This raises the difficulty of the assembly design, increases chances of failure and increases cost of production. Therefore, slightly larger round holes are much better suited for this purpose. Thus, the plate will have 5.5 mm diameter holes with a centre distance of 26 mm.

3.1 Material properties and weight calculations

1. Material: Mild steel Density: 7.85g/cm^3

Volume: 78.54 mm^3
Mass: 0.617g
We use two nuts in the assembly so total mass of nuts is 1.23g.

2. Material: Mild steel

Density: 7.85g/cm^3

Volume: 16679 mm^3
Mass: 130.93g

3. Material: Mild steel
Density: 7.85g/cm^3
Volume: 175.92 mm^3
Mass: 1.38g
We use two washers in the assembly so total mass of washers is 2.76gm

4. Material: Mild steel

Density: 7.85g/cm^3

Volume: 1287.01 mm^3
Mass: 10.1 g

5. Material: Mild steel
Density: 7.85g/cm^3
Volume: 1209.02 mm^3
Mass: 9.5 g
We use two screws in the assembly so total mass of screws is 19.0 g.

Component design

Nut, Plate

Fig 3.1 Model nut

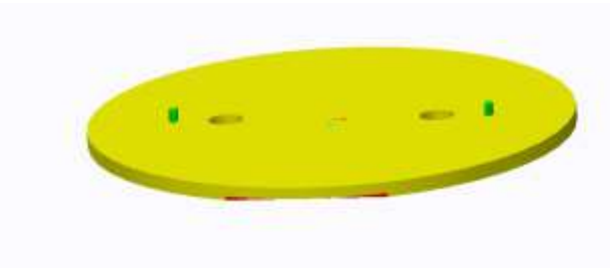


Fig 3.2 Model plate

Washer

Fig 3.3 model washer

Bearing housing, Bolt

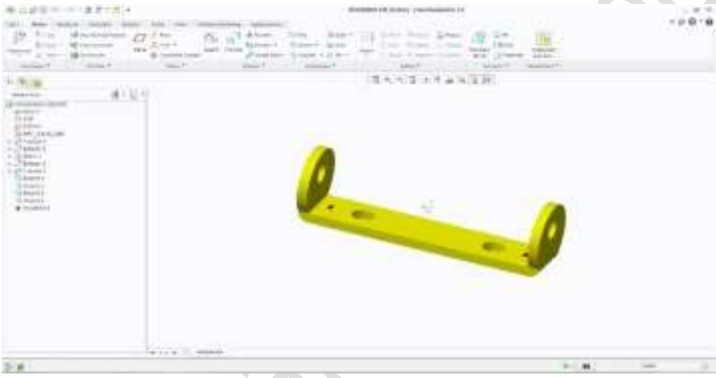


Fig 3.4 model bearing housing

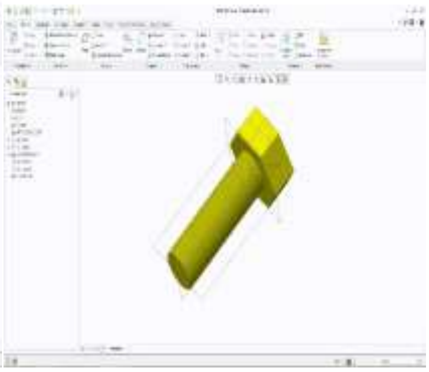


Fig 3.5 model nut

Fixture assembly with plate, Assembly2 (without plate)

The design of the fixture is a crucial aspect of robotic assembly. The fixture is used to hold the individual components in a fixed place and orientation while the robotic manipulator assembles the parts. The fixture thus also works to provide counter-force whenever the robotic manipulator needs to exert force on the assembly.

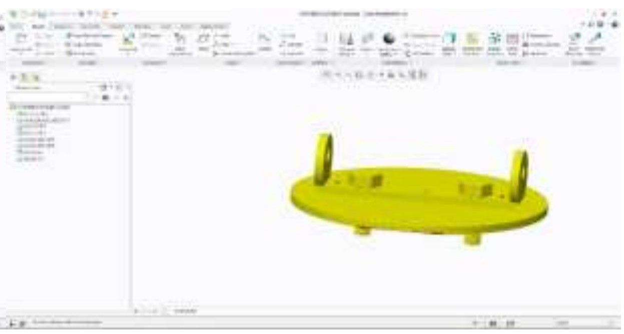


Fig 3.6 Fixture assembly with plate

Fig 3.7 Fixture assembly without plate

4.0 Process of assembly

- The first part placed within the fixture is the nut. For this, hexagonal undercuts have been provided in the fixture at the appropriate location and orientation required to place the nut. The width of the nut's holder will be slightly more than that of the nut, at 8.1 mm, in order to accommodate minor errors in placement orientation without affecting the operation of the assembly itself. The other dimensions of the undercuts will be exactly the same as the dimensions of the nut.
- The second undercut, placed above the nut's undercut, is for the washer. Since the washer is round, the undercut has been made exactly to the specifications of the washer as changes in orientation while placing the washer are irrelevant.
- The undercuts highlighted in green are provided for the gripper to open and close as required. Since the circular fingers, used for manipulating the nut, washer and screw, are larger than the other two fingers intended to be used for the plate and bearing housing, therefore these undercuts will be sufficient to avoid troubles when placing the plate and housing as well.
- The next undercut is for the plate which will be placed on top of the washers. The grooves previously placed on the plate will fit on top of symmetric complementary projections in the fixture that are 0.4 mm thick. Thus, the projections are slightly smaller than the grooves but are still capable of locking the plate's orientation.
- Next, the bearing housing will be placed on top of the plate, with the D-Shaped poles on the plate locking the housing in place. Since the plate itself is already locked by its grooves, the housing will become locked as well. Similarly, the screws will be placed in their appropriate slots on the housing, and due to the circular, slightly larger holes on the housing and plate, will slide partly inside and become locked in place until the robotic manipulator's screw driver tightens the bolts.

It is important to note that chamfers may be placed on all undercuts in order to allow parts to smoothly slide into place when placed by the robot.

Bearing Housing

The bearing housing will be picked up in the same manner as the plate, Again, the feeder is responsible for orienting the housing for the gripper before it is picked up.

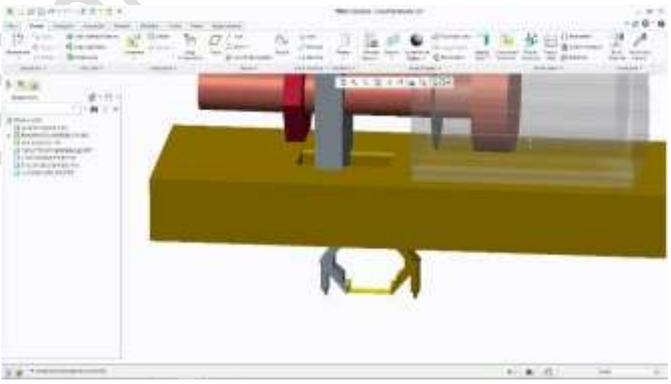


Fig 4.0 Bearing Housing model with gripper

Plate

In order to pick up the plate, the circular fingers of the gripper will be placed within the holes for screws in the plate in a closed position. Subsequently, the gripper will move to an open position in order to grab the plate. After positioning the plate correctly on the fixture, the gripper will move to the closed position again in order to release the plate. It is notable that in the closed position, the circular fingers are almost centered on the holes of the plate. As with the nut and washer, the feeder is responsible for ensuring that the plate is available in a flat, parallel, appropriate orientation when the gripper picks it up.

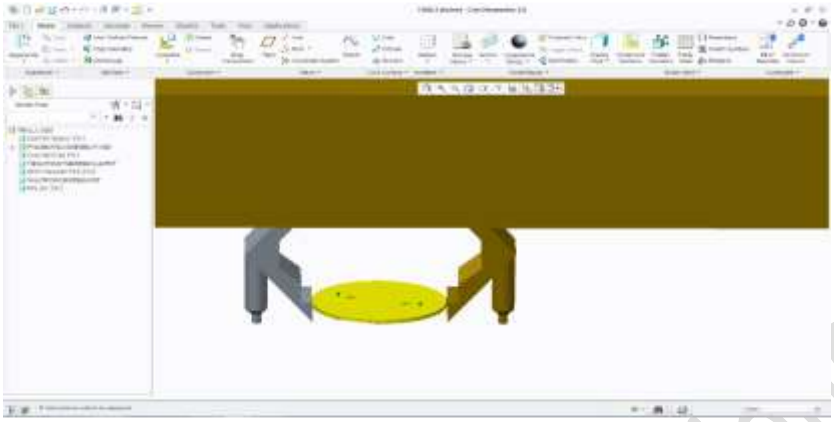


Fig 4.1 plate model with gripper

Washer

The details and conditions of picking up and placing the washer are effectively the same as that of the nut.

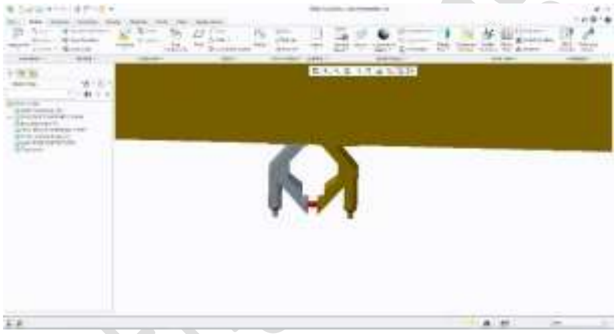


Fig 4.2 Washer model with gripper

4.0 Cycle time analysis

The manufacturing cell is the location where all the individual parts of an assembly are brought together and joined into a completed whole by the robot. Its design is important as this design determines how efficiently a robot is able to assembly the parts into a product. Total Cycle-time is how much time is taken by the robot to assemble one finished product and optimization of cycle-time directly improves manufacturing efficiency of the whole robotic assembly. Simultaneously, the manufacturing cell is one of the most hazardous units of the robotic assembly on account of the presence of a robotic arm which is capable of carrying a respectable payload as well as possesses considerable arm reach. Therefore, safety concerns must also be addressed when designing the manufacturing cell.

In the design presented below, the five components of the assembly are arranged such that they form a semi-circle about the robot mount at incremental 30^0angles and a radial range of 380 mm which is well within the arm reach of the robot. The assembly fixture is placed at the 0^0 mark at a distance of 180 mm from the robot mount. The conveyor belt carrying finished products is position at $+90^0$ from the robot mount at a similar distance as the fixture, that of 180 mm. In the Home position, the robotic arm aligns itself along the 0^0mark with all joint angles at 0^o. The parts' feeders are ordered so as to minimize the total distance that the arm must move in each cycle.

Cycle Time Analysis

We will use the slowest joint's speed as the estimator for velocity. Therefore, the angular velocity is 250°/s. The associated linear velocity can be estimated by the formula

$$v = r * \omega$$

Where v is the linear velocity, r is the radius of rotation and ω is the angular velocity in radians per second. We will use the maximum distance from Origin (O) to any feeder as radius of rotation to calculate the maximum associated linear velocity, i.e. r is400 mm. Hence, linear velocity v is calculated as

$$v = 400 * 4.3633$$
$$v = 1745.32\ mm\ s^{-1}$$

As specified, 90%, 50% and 10% of maximum speed will be utilized for fast, medium and slow movements. Therefore, all long distance horizontal movements will be considered to have a "fast" speed of 1570.788 mm/s, all vertical movements will have a "medium" speed of 872.66 mm/s, and all small distance horizontal movements will have a "slow" speed of 174.53 mm/s.

For linear movements,

$$T = \frac{d}{v}$$

Where T is cycle time, d is distance and v is linear velocity.

For angular movements,

$$T = \frac{\theta}{\omega}$$

Where T is cycletime, θ is angular displacement and ω is angular velocity.

The total cycle-time calculation will also include a delay time for initiating all movements.

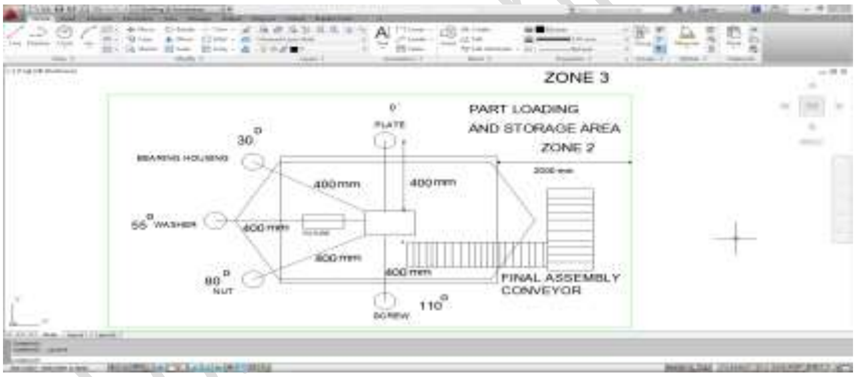


Figure 7.1 Robot Manufacturing Work Cell Layout

Nut Assembly

Movement Number	Movement	Distance	Speed (mm/S)	Time (S)
1	Home Position(O) to Nut Feeder(N)	200 mm	1570.788	0.12
2	Rotate the Upper arm to get the finger alignment	90°	225°/Sec	0.4
3	N to Nut Feeder origin (N_O)	100 mm	872.66	0.11
4	Gripper Close	Standard	Standard	0.05
5	Movement (N_O) to (N)	100 mm	872.66	0.11

6	N to Fixer Nut Assembly 1 ($F.N_1$)	200 mm	1570.788	0.127
7	F.N1 to Fixer Nut Assembly Origin ($F.N_O$)	100 mm	872.66	0.11
8	Gripper Open	Standard	Standard	0.05
9	Movement Up $F.N_O$ to $F.N_1$	100 mm	872.66	0.11
10	$F.N_1$ to Home (O)	13 mm	Standard	0.05
	Delays (0.01x10)			0.10
Total				**1.337**

Cycle time for single Nut Assembly = 1.377 Sec.
Cycle time for Assembly of Two Nuts = 2.674 Sec.

Washer Assembly

Movement Number	Movement	Distance	Speed (mm/s)	Time (S)
1	Rotating Home Position Axis to Washer Feeder Axis Alignment	30°	225°/s	0.133
2	Washer Axis to Washer Feeder (W)	200 mm	1570.788	0.12
3	Rotate the Upper arm to get the finger alignment	90 °	225°/s	0.4
4	Moves Down W to Washer Feeder Origin (W_O)	100 mm	872.66	0.11
5	Gripper Closed	Standard	Standard	0.05
6	Moves Up (W_O) to (W)	100 mm	872.66	0.11
7	Joint Interpolation W to Fixer Home Position 1 ($F.W_1$)	200 mm	1570.788	0.12
8	Moves Down $F.W_1$ to Fixer Washer Assembly Origin ($F.W_O$)	100 mm	872.66	0.11
9	Gripper Open	Standard	Standard	0.05
10	Movement Up $F.W_O$ to $F.W_1$	100 mm	872.66	0.11
11	$F.W_1$ to Home (O)	13 mm	Standard	0.05
	Delays (0.01x10)			0.10
Total				**1.46**

Cycle time for single Washer Assembly =1.46 Sec.
Cycle time for Assembly of Two Washers = 2.92 Sec.

Plate Assembly

Movement Number	Movement	Distance	Speed (mm/s)	Time (S)
1	Rotate Home Position Axis to Plate Feeder Axis	60°	225°/s	0.266
2	Plate Feeder Axis to Plate Feeder (P)	200 mm	1570.788	0.12
3	Rotate the Upper arm axis to match the fingers to plate holding position	90 °	225°/s	0.4
4	Moves Down P to Plate Feeder origin (P_O)	100 mm	872.66	0.11
5	Gripper open	Standard	Standard	0.05
6	Moves Up (P_O) to (P)	100 mm	872.66	0.11
7	Rotation from Plate axis position (P) to Home position axis	60°	225°/s	0.266
8	Joint Interpolation Home position axis to Fixer Plate Assembly (F.P)	200 mm	1570.788	0.12
9	F.P to Fixer Plate Assembly Origin ($F.P_O$)	100 mm	872.66	0.11
10	Gripper close	Standard	Standard	0.05
11	Movement Up $F.P_O$ to home position	100 mm	872.66	0.11
	Delays (0.01x10)			0.10
Total				**1.812**

Cycle time for single Plate Assembly = 1.812 Sec.

Bearing Housing Assembly

Movement Number	Movement	Distance	Speed (mm/s)	Time (S)
1	Rotate Home Position Axis to Bearing Housing (B.H) Axis	60°	225°/s	0.266
2	Moves Forward B.H Axis to B.H Feeder	200 mm	1570.788	0.12

3	Rotate the Upper arm axis to match the fingers to holding position	90º	225º/s	0.4
4	Moves Down B.H to Bearing Feeder origin ($B.H_O$)	100 mm	872.66	0.11
5	Gripper open	Standard	Standard	0.05
6	Moves Up ($B.H_O$) to (B.H)	100 mm	872.66	0.11
7	Rotation from Bearing axis position (B.H) to Home position axis	60º	225º/s	0.266
8	Joint Interpolation Home position axis to Fixer Bearing Assembly (F.B)	200 mm	1570.788	0.12
9	F.B to Fixer Bearing Assembly Origin ($F.B_O$)	100 mm	872.66	0.11
10	Gripper close	Standard	Standard	0.05
11	Movement Up $F.B_O$ to home position	100 mm	872.66	0.11
	Delays (0.01x10)			0.10
Total				**1.81**

Cycle time for Bearing Housing Assembly = 1.81 Sec.

Screw Assembly

Movement Number	**Movement**	**Distance**	**Speed (mm/s)**	**Time (S)**
1	Rotating Home Position Axis to Screw Feeder Axis Alignment	30º	225º/s	0.133
2	Screw Axis to Screw Feeder (S)	200 mm	1570.788	0.127
3	Rotate the Upper arm to get the finger alignment	90º	225º/s	0.4
4	Moves Down S to Screw Feeder Origin (S_O)	100 mm	872.66	0.11
5	Gripper Closed	Standard	Standard	0.05
6	Moves Up (S_O) to (S)	100 mm	872.66	0.11
7	Joint Interpolation S to Fixer Home Position 1 ($F.S_1$)	200 mm	1570.788	0.127
8	Moves Down $F.S_1$ to Fixer Screw Assembly Origin ($F.S_O$)	100 mm	872.66	0.11
9	Gripper Open	Standard	Standard	0.05
10	Movement Up $F.S_O$ to $F.S_1$	100 mm	872.66	0.11

Vol 11, Issue 4 , April/2020
ISSN NO:0377-9254

11	$F.S_1$ to Home (O)	13 mm	Standard	0.05
	Delays (0.01x10)			0.10
Total				**1.477**

Cycle time for single Screw Assembly = 1.477 Sec.
Cycle Time for Assembly of Two Screws = 2.954 Sec.

Screwing of Assembled Screws

Movement Number	Movement	Distance (mm)	Speed (mm/s)	Time (S)
1	Arm moves linearly to Screw 1 position	13 mm	Standard	0.05
2	Moves down to Screw 1 origin	100 mm	872.66	0.11
3	Ratchet gun fit to screw head	Standard	Standard	0.05
4	Ratchet gun operation	Standard	Standard	0.15
5	Arm Moves up	100 mm	872.66	0.11
6	Arm moves linearly to home position	13 mm	Standard	0.05
7	Arm moves linearly to Screw 2 position	13 mm	Standard	0.05
8	Moves down to Screw 2 origin	100 mm	872.66	0.11
9	Ratchet gun fit to screw head	Standard	Standard	0.05
10	Ratchet gun operation	Standard	Standard	0.15
11	Arm Moves up	100 mm	872.66	0.11
12	Arm moves linearly to home position	13 mm	Standard	0.05
	Delays (0.01x12)			0.12
Total				**1.16**

Cycle Time for Tightening 2 screws by Ratchet Gun = 1.16 Sec

Move Completed Assembly to Conveyor

Movement Number	Movement	Distance	Speed (mm/s)	Time (S)
1	Arm moves down to Fixer Screw 1 center position	100 mm	872.66	0.11
2	Gripper Close	Standard	Standard	0.05
3	Arm moves up to home position	100 mm	872.66	0.11
4	Rotate from home position to assembly center axis alignment	90^{o}	225^{o}/s	0.4

5	Arm moves down towards conveyor	100 mm	872.66	0.11
6	Gripper Opens	Standard	Standard	0.05
7	Arm moves up	100 mm	872.66	0.11
8	Rotate from assembly center axis alignment to home position	90º	225º/s	0.4
	Delays (0.01x10)			0.10
Total				**1.44**

Cycle time for moving the assembled part to conveyor belt = 1.44 Sec.

Total Cycle Time Calculation :

Cycle time for two Nuts Assembly = 2.674 s
Cycle time for two Washers Assembly = 2.92 s
Cycle time for single Plate Assembly = 1.812 S
Cycle time for Bearing Housing Assembly = 1.81 S
Cycle time for two Screws Assembly = 2.954 s
Cycle Time for Tightening 2 screws by Ratchet Gun =1.16 s
Cycle time for moving the assembled part to conveyor =1.44s

Total Cycle is 14.77 seconds

5.0 Conclusions

A robotic work cell, like any other manufacturing environment, carries the potential for accidents to occur which may result in loss or damage to human life and property. The most common cause for most accidents is human error. Even though robotic assemblies are operated by robots and not humans, it is impossible to eliminate the presence of humans completely. Hence, it is necessary to take steps to make the work environment as safe and risk-free as possible. This includes imposition of safety protocols and rules. An attempt made to control the cycle time analysis for future work. The report also outlined the layout of a cell, including safety functions and optimization of assembly operations. In this connection, the design process for the montage can be considered almost complete, pending examination and of course scope for improvements.

6.0 References

[1] N. Brauner and G. Finke, "Cycles and Permutations in Robotic Cells," Mathematical and Computer Modelling, 34, 565-591 (2001).

[2] N. Brauner, G. Finke, W. Kubiak, "Complexity of One-Cycle Robotic Flow-Shops," Journal of Scheduling, 6, 355-371 (2003).

[3] A. Che, C. Chu, F. Chu, "Multicyclic Hoist Scheduling with Constant Processing Times," IEEE Transactions on Robotics and Automation, 18, 1, 69-80 (2002a).

[4] A. Agnetis, "Scheduling No-Wait Robotic Cells with Two and Three Machines," European Journal of Operational Research, 123, 303-314 (2000).

[5] A. Agnetis, D. Pacciarelli, "Part Sequencing in Three Machine No-Wait Robotic Cells," Operations Research Letters, 27, 185-192 (2000).

[6] E. Ak¸calı, K. Nemoto, R. Uzsoy, "Cycle-Time Improvements for Photolithography Process in Semiconductor Manufacturing," IEEE Transactions on Semiconductor Manufacturing, 14, 48-56 (2001).

[7]LaValle SM (2006) Planning Algorithms. Cambridge: Cambridge University Press. LaValle SM and Kuffner JJ (2001) Randomized kinodynamic planning. The International Journal of Robotics Research 20: 378–400. Manchester, IR (2010)

[8] Mettin U, Iida F and Tedrake R (2009) Transverse dynamics and regions of stability for nonlinear hybrid limit cycles. arXiv:1010.2241 Manchester IR, Stable dynamic walking over rough terrain: Theory and experiment. In

Vol 11, Issue 4 , April/2020
ISSN NO:0377-9254

Proceedings of the International Symposium on Robotics Research (ISRR), Lucerne, Switzerland.
[9] Shkolnik A, Walter M and Tedrake R (2009) Reachabilityguided sampling for planning under differential constraints. In Proceedings of the IEEE/RAS International Conference on Robotics and Automation (ICRA 09), Kobe, Japan, pp. 2859–2865.