International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 06, June-2015

# Design and Automation of HSU Assembly Station by Poka Yoke

Sachin RS
Mtech PDM student
National Institute of Engineering
Mysore

Asst. Prof. Ravikumar Beeranur,
National Institute of Engineering
Mr. Sharavanan
Production Head (Rane Madras Limited)
Mysore

***Abstract-*** **Manufacturing companies are continuously facing the problem of operating their manufacturing and assembly process, in order to deliver the required production rates with high quality, it is required to makes the product customization and short time to market increases the competition among the global manufacturer. The module has analyzed in RANE Madras Company in Mysore. This paper describes the assembly automation of HSU (Hydrostatic steering unit) using poka yoke technique over manual assembly process by considering mistakes in the manual process and cost, quality, production, lead time under demand fluctuation. The methodology includes FMEA of manual assembly process. The selection of final concept by generating 4 concepts using Pugh matrix method and finally detailed design of selected concept has been well tested. As per the obtained results, it is possible to reduce the human mistakes up to zero percent and reducing the cycle time from 20 seconds to 10 seconds.**

***Key words: poka yoke, automation, PFMEA, HSU***.

## INTRODUCTION

Assembly is a production system where flow-oriented production units making the operations, referred to as by number stations are aligned in a serial fashion. The integration of product and human activities for achieving total value ensure economic growth [3]. However, within a production/assembly process, several products can present defects (e.g. wrong part insertion, performing the assembly in an incorrect manner, etc) that may be attributed to the human factor. Causes such as negligence, finite memory, and knowledge or competence errors are the ones responsible for most errors encountered during assembly [4]. For the minimization of the number of defects during the assembly process, these factors need to be analyzed in order to bring up the means of either predicting the possibility of a defect, or reducing the overall probability of such an occurrence. Towards this goal, the first step is the identification of possible errors and error types that may become present during the assembly. The assembly process is conducted manually and automatically using assembly machines. The term “assembly automation” refers to the fastening of manufactured components into a complete product assembly. The tooling and equipment is dedicated to a particular product, automated assembly is generally dedicated for mass-produced components, where the expense of custom tooling and equipment can be distributed over many units [5]

Automation Assembly Systems are categories based on the type of work transfer. The assembly system is divided into following categories: 1.Continuous transfer system, 2.Synchronous transfer system, 3.Non-synchronous transfer system 4. Stationary base part system. In the first three types, the work part transport is described in automated flow line. In the stationary base part system, the base part is in the fixed location where the other components are added automatically. Synchronous system cyclically indexes the products simultaneously to individual machines with fixed frequency. In non synchronous system, the assembly machines operated independently and the index time depends upon the tasks time of each machine.

In continuous system, the assembling product remains in constant motion and the tasks are performed while the product travels.

Based on physical configuration, the assembly system is divided into following categories:

1 Dial-type assembly machine 2 In-line assembly machine 3Carousel assembly system 4Single-station assembly machine

In-line type configuration

The in-line configuration assembly system is the most popular system and consists of many workstations in a straight-line manner arrangement in the sequentially. The in-line assembly machine consists of automatic workstations arranged in series and located along an in-line transfer system. In the present study in-line assembly system has been installed.

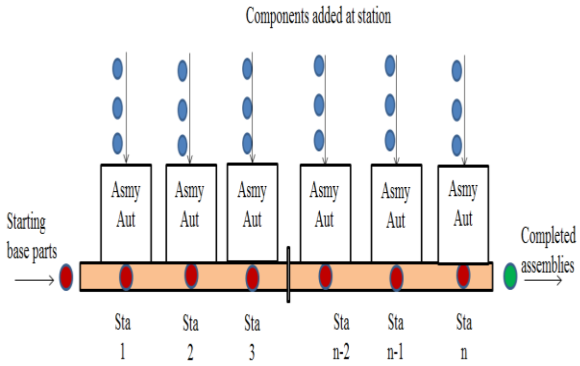


Fig.1. In line type assembly system

## II. LITERATURE SURVEY

. An attempt is made in literature survey to highlight the work done by various researchers on relevant to this topic. Many researchers have done a research on the assembly automation, poka yoke and FMEA. Based on that papers design and automate the HSU assembly station. Besides that explains the types of automation, types of poka yokes, sensors, FMEA and their definitions.

### *2.1 Assembly Automation*

The term "assembly automation" refers to the mechanized feeding, placement, and fastening of manufactured components into a complete product assembly.

Automation is the only force behind the rationalization of manufacturing process to increase the competitiveness and productivity, which makes high degree of machine utilization, reduction in process inventory, reduced time to market. Rhythm.Suren Wadhwa et.al [2] found that SMEs industries over 65% of total manufacturing time spent in manual handling of materials. It was also found that the cost of manufacturing a product is between 30% and 40% of total manufacturing cost. Asar Khan et.al[5] made a research on A Knowledge Based Design Methodology for Manufacturing of manual and automated Assembly Lines. The methodology includes suitable assembly system selection, suitable cycle time selection, type of assembly system being selected, and an economic number of workstations decided. The end result is the detail design of the manufacturing assembly line. Which in turn increase line efficiency from 71% to 88.75% and the production rate from 690 to 823 units per day.

### *2.2Poka Yoke*

Poka-yoke, a term introduced by a Japanese engineer named Shingo Shingo in 1960s, suggests mistake or error-proofing in the assembly line.. This concept was significantly made the changes in the quality profession in Japan. Originally called "fool proofing" and later changed to "mistake proofing" or "error proofing". The main purpose of Poka-Yoke is to avoid defects from mistakes using the simplest and lowest-cost techniques possible. Poka-Yoke is implemented to the simple objects like fixtures, jigs, gadgets, warning devices to prevent the people from making mistakes—even if they try to do. These objects are known as Poka-Yoke devices and usually used to stop the manufacturing process and signals the operator if something is about to go wrong [1]. Nilesh.S.et.al [1] Implement the poka-yoke on the fixture; it consists of spring pin sensor mechanism and proximity sensor. This makes the automation to detect wrong assembly, and eliminate 100% error in the assembly line and increased production rate. Fast- Berglund et.al [3] also worked on the assembly errors, over 60% of all the tasks were performed based on own experience and he studied all the assembly stations and find out with highest and lowest errors, to avoid this accomplished by pick by lights system guiding the assembly operation, which is based on poka-yoke system. The parts are stored in the bin to assemble the component where the lights are installed in all the bins which signal the operator by blinking light to assemble sequentially without making errors. Dinesh.D et.al [8] has stated poka yoke is one of the lean manufacturing tactics which prevents errors before they become defects. Siddhartha Sharm et.al [9] implement the poka yoke technique through electronic sensors like proximity, photo electric and magnetic reed switch on the various assembly line and getting the results by drastically reducing the cost of production , enhancing customer satisfaction and confidence.

### *2.3 PFMEA*

Potential Failure Modes and Effects Analysis is a methodology designed to identify potential failure modes for process or product before they occur. It is an important preventive method for quality assurance and the decisions based on the severity levels. Probabilities of occurrences and detection of the failure modes can be planned and prioritized. This helps to improve the quality of the manufactured products [7].

The focus of standard FMEA is usually on providing quality parts and reducing frequency of problems. Severity(S) ratings are usually linked to the ability to provide quality products to the customer. An occurrence (O) rating gives an indication of the frequency of the problem. Detection(D) ratings are an estimation of the effectiveness of problem prevention and containment. The Risk Priority Number (RPN) is a product of the Severity, Occurrence, and Detection ratings: SxOxD=RPN. And it should be always low, if it is high chances of problems occurrences and detection is high [10].

## III. METHODOLOGY

The implementation of new assembly station is due to the need established by the market demand. To satisfy the customer demand, production has to increase and mean while get a quality of product with zero defects. The current assembly process done by manually and it cannot meet the customer demand due to increase in cycle time and human error. So in order to increase the rate of production, poka yoke has been installed in the in-line assembly stations.

*3.1Existing Study of manual assembly station:*

The existing Study of manual assembly is shown in the fig 2. It takes the assembly process time of HSU nearly 1200 secs.

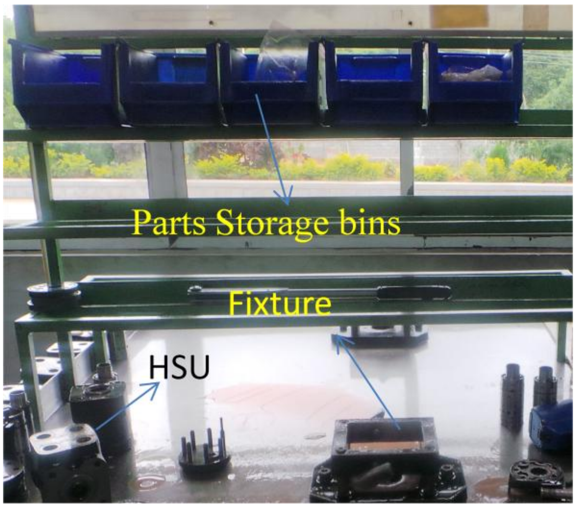


Fig. 2 Manual assembly station of HSU

The requirement of the product has been calculate as follows.

Present output /shift

Available work time/shift

= 8-1 = 7hrs = 420min.

Output/shift

$$= \frac{\text{Available work time/shift}}{\text{Cycle Time}}$$

= 420min/20min=22units.

For 2 shifts 22×2=44 units.

For 1month 44×25=1100units.

HSU unit requirement for 1month is 4000 units

$$\text{Talk time} = \frac{\text{Available work time/month}}{\text{Customer demand}}$$

= 21000/4000= 5.25min.

To reach the customer demand of 4000 units they should produce a HSU component at the rate of 5.25 minutes.

*3.2 Design of HSU assembly Layout:*

To fulfill the customer needs of 4000units/month, the new assembly station layout has been designed and developed.

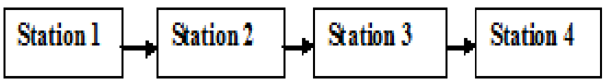


Fig.3 Automated HSU assembly station layout

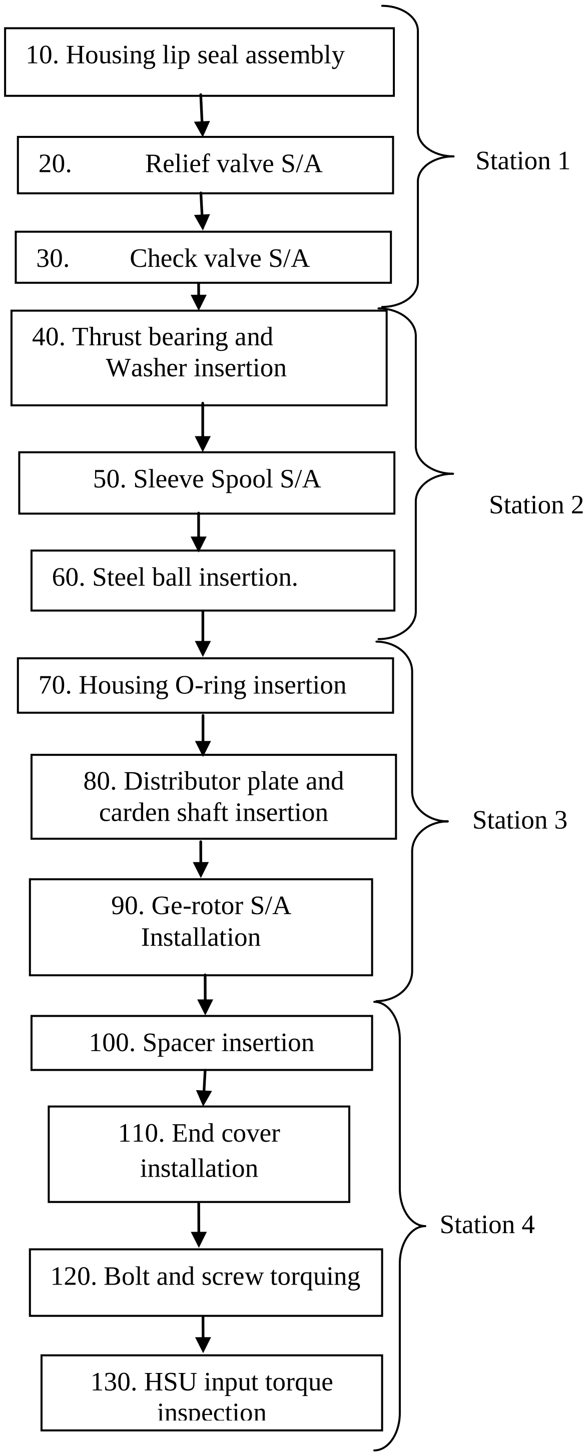


Fig.4 Sequence of the assembly process in their respective stations.

The Fig.3 shows the designed HSU assembly station layout, each station carries particular assembly process. To make automation, reducing assembly errors in between the stations, poka yokes logic and programmable logic controller (PLC) is introduced.

The Fig.4 shows the planned sequential and station wise assembly process of the HSU component. Assembly station 2 is selected to design and automate by considering time, and cost to implement the station, which is shown in the Fig.4.

### *3.3 PFMEA*

Potential Failure Modes and Effects Analysis is a systematic and proactive method for evaluating an assembly process. The possible assembly failure problems are listed for the thrust bearing, washer, sleeve spool S/A, and steel ball. Severity, occurrence, detection rankings are given to those assembly problems and find out the Risk Priority Number (RPN). As per the table 2. the highest RPN obtained in the thrust bearing, washer, sleeve spool S/A, and steel ball assembly process was 168, 168, 240 and 168 respectively

Table 2.potential failure modes and effective analysis

| Process/ function | Requirements | Potential failure mode | Potential effects of failure | Current process controls | S | O | D | RPN | Actions taken | S | O | D | RPN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10. Thrust Bearing insertion | Thrust bearing should seat perpendicular to the housing face in the desired groove | Assembly without/with fewer bearing Races | NP-Free rotation<br>C- Free rotation /unable to steer<br>EC-No response | Detection in performance test | 7 | 3 | 6 | 126 | Auto loading | 7 | 3 | 3 | 63 |
| | | Assembly with more bearing Races | NP-unable to assemble<br>C-high torque /steering jam<br>EC-Hard steering /steering jam | 100% inspection for free movement | 7 | 3 | 6 | 126 | Auto loading | 7 | 3 | 3 | 63 |
| | | Missing of bearing insertion | NP-Free rotation<br>C-Free rotation/unable to steer | 100% inspection for free movement | 7 | 4 | 6 | 168 | Auto loading with poka yoke | 7 | 3 | 2 | 42 |
| 20.Washer insertion | Washer should be perpendicular to the housing face in the desired groove | Assembly without washer | NP-Free rotation<br>C-High torque/steering jam<br>EC-Loss of steering | 100% inspection for free rotation | 7 | 4 | 6 | 168 | Auto loading with poka yoke | 7 | 3 | 3 | 63 |
| | | Assembly with more washer | NP-Free rotation<br>C-High torque/steering jam<br>EC-Hard steering | 100% inspection for free rotation | 7 | 3 | 6 | 126 | Auto loading | 7 | 3 | 2 | 42 |
| 30. Steel ball insertion | Steel ball should insert to the hole of pump connecting line | Assembly without steel ball | NP-External Leakage<br>C-External leakage<br>EC-External leakage | 100% visual inspection & Ex ternal leakage detection | 7 | 3 | 6 | 126 | Auto loading with poka yoke | 7 | 3 | 2 | 42 |
| | | Assembly with more steel balls | NP-External Leakage<br>C-External leakage<br>EC-External leakage | 100% visual inspection & Ex –ternal leakage detection | 7 | 3 | 6 | 126 | Auto loading | 7 | 3 | 3 | 63 |

### *3.4 Concept generation and selection*

In the concept development stage many three dimensional models were generated by considering assembly error, space requirement and equipment cost in mind. The team reviews the sketches or CAD models and promising, viable diagrams are taken for the further development process.

Table.1 Pugh matrix used for screening and selecting the concepts

| Selection criteria | concept 1 (Reference) | concept 2 | concept 3 | concept 4 |
|---|---|---|---|---|
| Ease of Fabrication | 0 | + | + | + |
| Space requirement | 0 | + | + | + |
| Fabrication cost | 0 | + | + | + |
| Component handling | 0 | + | 0 | 0 |
| Operating speed | 0 | 0 | - | 0 |
| Total weight | 0 | + | 0 | 0 |
| Maintenance cost | 0 | 0 | + | 0 |
| Flexibility | 0 | + | - | 0 |
| Sum +'s | 0 | 6 | 4 | 3 |
| Sum 0's | 8 | 2 | 2 | 5 |
| Sum -'s | 0 | 0 | 2 | 0 |
| Net score | 0 | 6 | 2 | 3 |
| Rank | 4 | 1 | 3 | 2 |
| Continue | | | | Yes |

For HSU assembly station a total 4 concepts were generated, their total costs, space requirement, operating cost were specified. Based on the Pugh matrix methods these 5 concepts have been screened and evaluated, concept 2 is ranked as "1" and consider for further development, which is shown in the table.1.

*3.5 optimized station 2 and working procedure*

Optimized design station 2 consists of pneumatic circuit design, electric circuit design, and station components details. The Fig 5 shows the CAD model of concept 2; Thrust bearing washers and steel balls are stored in hoppers, these hoppers are placed above the sliding plate, which helps to carry a part on every forward movement of sliding plate, which is shown in the Fig. 9 and 10 and the operational details of the assembly process are given below.

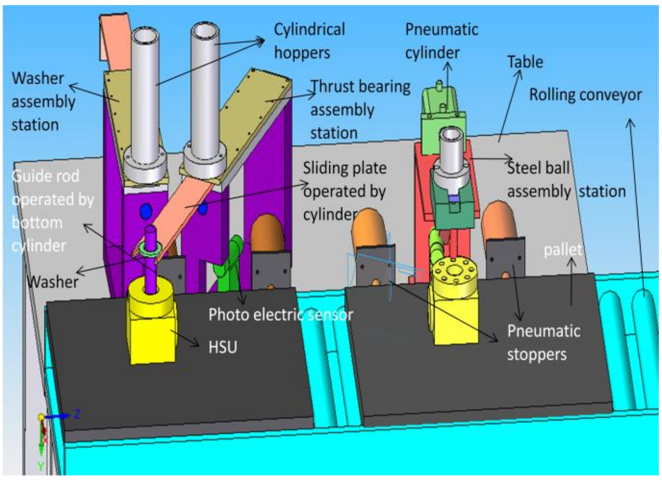


Fig.5 CAD model of optimized station 2

*3.5.1Operation of HSU assembly station*

The sequenced assembly operations of the HSU are as follows.

A) Photo electric sensor senses the presences of the housing component then stoppers actuates and locks the pallet. B).Initially cylinder is in the forward stroke and sliding plate which is connected to the piston rod is in the initial position. When cylinder retracts the sliding plate moves forward and carries the washer and reaches the end position. Cylinder is actuated using magnetic reed switch, solenoid operated DCV and is controlled by PLC, which is shown in the Fig.10. C) The bottom cylinder actuate forward and guide rod moves up. Guide rod passes through the housing component, washer, after that sliding plate moves backward. In the next sequence guide rod moves down, which carries the washer, get assembled into HSU component, this completes one washer assembly process.

The above two assembly steps of B and C repeats again in thrust bearing assembly station to assemble thrust bearing and in the washer assembly station to assemble washer. D) Steel ball station activates and actuates the cylinder then piston moves forward and sliding plate carries the steel ball get assembled into the HSU component, this completes the assembly process.

*3.5.2 ELECTRIC CIRCUIT DESIGN*

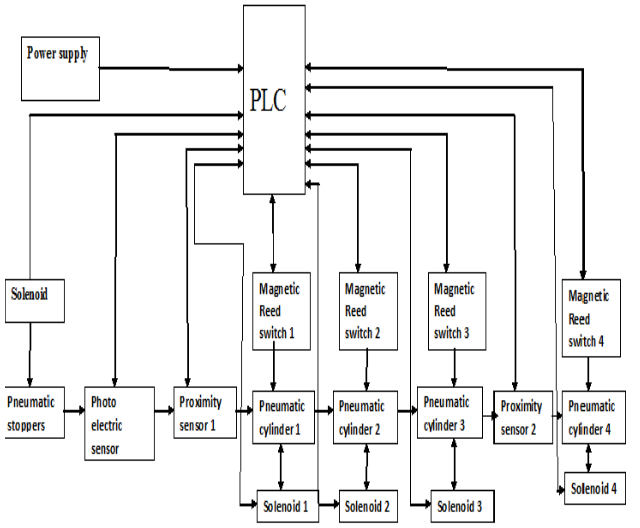


Fig.6 Electric circuit diagram of HSU assembly station

The Electric circuit design used to operate the stations is shown in the Fig.6 It consists of photo electric sensor to senses the component presence, proximity sensors, solenoids, magnetic reed switch and is controlled by PLC. Pneumatic cylinder1, 2, 3 and magnetic reed switch 1, 2, 3 and solenoid 1, 2, 3 are the components of the thrust bearing station, washer station, bottom cylinder and steel ball station respectively.

### *3.5.3 PNEUMATIC CIRCUIT DESIGN*

The Fig 7 and 8 shows the pneumatic circuit diagram used in the HSU assembly station. It consists of a double acting pneumatic actuator, 5/2 direction control valve operated by piloted solenoid valve, and flow control valve to control the speed of the sliding plate and guide rod.

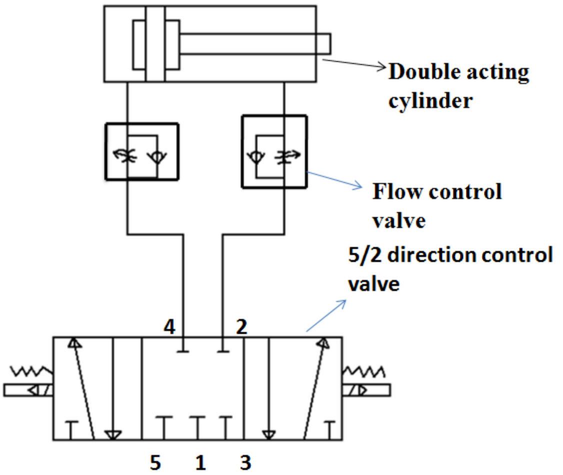


Fig.7 pneumatic circuit design of thrust bearing and washer station

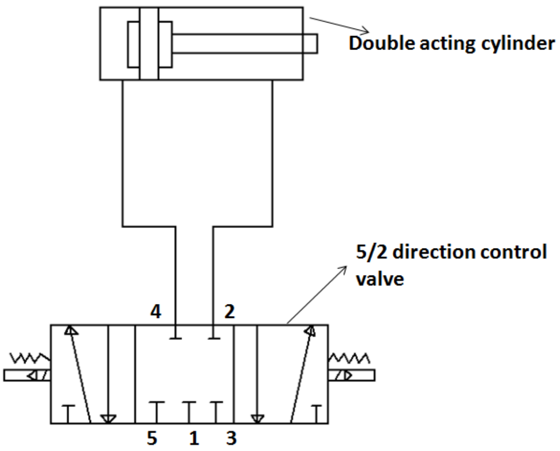


Fig.8 pneumatic circuit design of steel ball station.

## IV.TESTING AND RESULTS

The Fig 9 shows implemented HSU assembly station 2. In the testing operation washer and Thrust bearing get assembled during the forward movement of sliding plate successfully. Flow control valves are used controlling the of the sliding plate movement which is shown in the Fig.10 and 11. In the testing of the steel ball assemble station, steel ball get assembled during forward movement through the tube which is shown in the Fig 12. As per the test result assemble the HSU component by removing all the washers in the hopper meanwhile PLC stops the assembly process automatically. This is because proximity sensor does not send the signals to the PLC. This testing confirms the poke yoke implementation successfully.

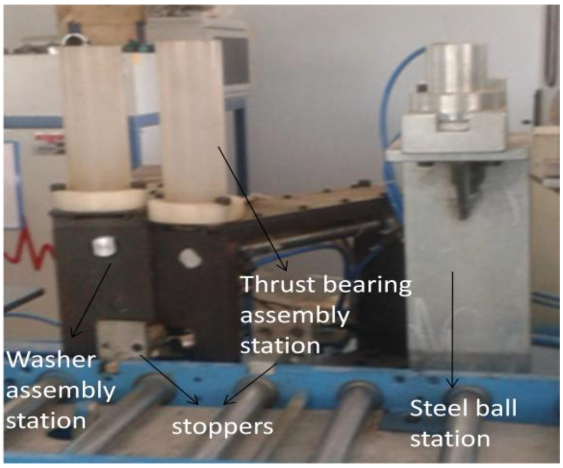


Fig.9 Implemented assembly station 2

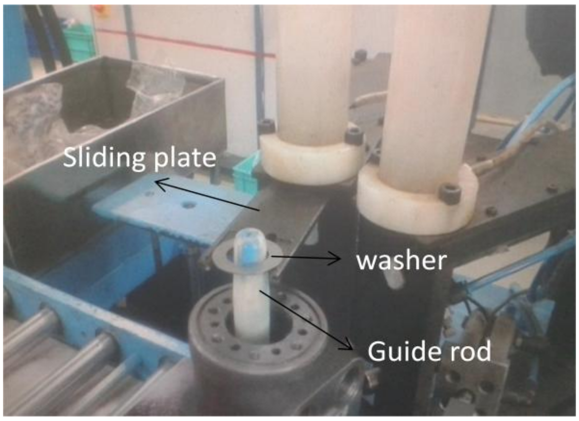


Fig.10 washer assembly of HSU component

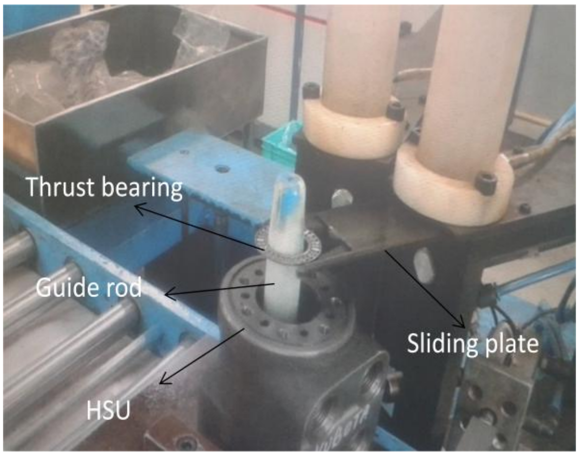


Fig.11 Thrust bearing assembly of HSU component

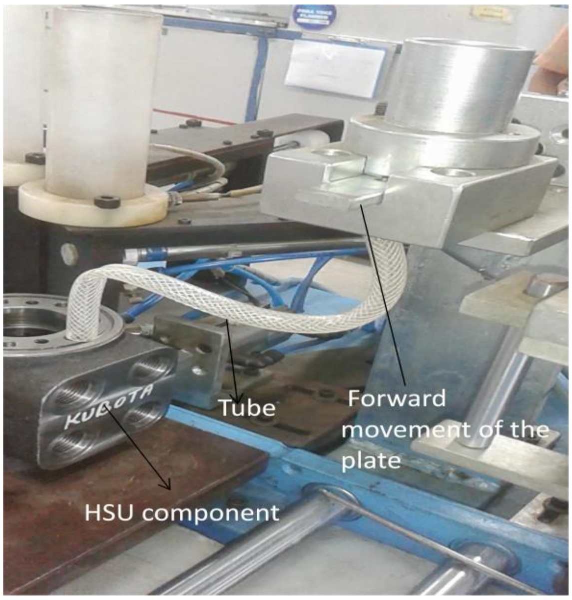


Fig.12 steel ball station

Performance Results shows 1) all the sensors work properly according to the PLC programmed and station cylinders, stoppers are worked accurately. 2) Thrust bearing, washer and steel ball assembly cycle time reduces from 20sec to 10sec.C) FMEA of risk priority number in HSU station 2 reduced to safer level which is shown in the Table.2.

## V.CONCLUSION

Automation of assembly station with poka yoke station solves the problem of human mistakes up to zero percent, which was happening in the manual assembly process. Assembly automation increases the rate of production by reducing the cycle time from 20 seconds to 10 seconds. As per the obtained results, the Risk priority number of assembly process is reduced by the introduction of automation in the HSU assembly process.

## ACKNOWLEDGEMENT

The authors would like to thank Rane (madras) Limited for giving the opportunity and financial support to conduct and carry the research here.

## REFERENCES

[1] Nilesh.S.Ahire, Uddhavrao M. Nimbalk---ar, Santosh R. Raijade., “Design and Impl- -emntation Of Mechanical Poka-Yoke System Using Programmable Logic Controller”, International Journal of Mechanical and Production Engineering, Vol.2, Sept. 2013, PP 213-240.

[2] Rhythm Suren Wadhwa, “Flexibility In Manufacturing Automation: A Living Lab Case Study Of Norwegian Metalcasting Smes”, Journal of Manufacturing Systems, Vol.31, 2012, PP 444 – 445.

[3] Fast-Berglund.A, Fässberg. T,Hellmanb. F, Davidssonc. A, Stahrea. J., “Relations between Complexity, Quality And Cogniti- -ve Automation in MixedModel Assembly”, Journal of Manufacturing Systems, Vol. 32, 2013, PP 449–455.

[4] Cristobal Miralles, “Universal design of workplaces through the use of Poka-Yokes”, Journal of Manufacturing Systems, Vol.33, 2011, PP 440 – 445.

[5] AsarKhan et.al, Andrew J,“A Knowled –ge Based Design Methodology for Manufa --cturing Assembly Lines”, computers and industrial engineering, vol.41, 2002, PP 441-467.

[6] R. Ryan Vallance, Chris Morgan, Alexander H. Slocum, “Precisely positioni --ng pallets in multi-station assembly systems” Precision Engineering, vol. 28, 2004, PP- 218- 231.

[7] Chao-Ton Su, Hung-Chun Lin , Po-Wen Teng , Taho Yang, “Improving the reliability of electronic paper display using FMEA and Taguchi methods”, Microelectronics Reliability, vol. 54, 2014, PP 1369–1377.

[8] **K.** velmanirajan, g.rajaraman, s.k.karthi --keya, D.dinesh,“lean manufacturing in cha- -sis assembly through poka-yoke”, Internat--ional journal of technology enhancements and emerging engineering research, vol. 1, 2013,PP 2347-4289.

[9] siddarth, sharma, “Implementation of poka-yoke using electronic sensors”, precision engineering, vol.35, 2013, PP 123-130.

[10] Seung J. Rhee, Kosuke Ishii, “Using cost based FMEA to enhance reliability and serviceability”, Advanced Engineering Informatics, vol.17 2003,PP- 179–188.