Quality Improvement of Small Form-Factor Pluggable (SFP) Units Assembly Using Robotic Automated System

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Abstract Automated mechanization in other word referring to various tasks and jobs done by human is replaced by automated system. In the manufacturing processes, automated conveyor system and automated plant control processes are among the automated system applied to improve the process efficiency. In this study, an automated assembly process using robotic system to replace conventional manual assembly process is investigated. The objective of this study is to improvise the manual bail, latch, and shell assembly processes that causes many defects quality. Thus, a new robotic machine is built to reduce the quality errors of the assembled product and increases efficiency of the assembly process. As the results, the robotic machine increases the productivity by 99%, while the defect rate has been reduced from 10.31% to 0.27%. .

Keywords Industrial Robotics · Quality · Productivity · SFP

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1 Introduction

In the past years, the role of robotics arm replaces the human manpower is picking up the pace as many industries are implementing more automation system. The robotics arms, usually made up of 4–6 joints which can be for several manufacturing applications such as assembly process, welding, and material handling professions (Graetz and Michaels 2015). An industrial robot arm can be defined as a marvel of engineering in that it reacts similarly to our own arms. It closely resembles a human arm with a wrist, forearm, elbow, and shoulder. The use of industrial robots increases the potential of replacing human labor by reducing human interaction in controlled operations (McCutcheon and Pethick 2014). Automation can benefit many businesses. Solar panel, tires, and semiconductors among the industry that implemented robotic system in the production line. Robotics is used when high intelligence is required (Vosniakos and Matsas 2010). Since robots are more precise compared to physical labor, many experts believe cheaper, better robots may replace human labor in the next decade hence lowering labor expenses (Asbeck et al. 2014).

Trending the 4.0 industrial revolution, robotics not only applied in developed countries, while many developing countries is also utilizing the benefit of robotics system in the production (Accenture 2016). Robust machines and robot's core save the most energy and overhead cost since robot can precisely repeating the same task with acceptable accuracy (Asbeck et al. 2014). As technology advances, robotic technology is quickly expanding its operations integrated with vision system to improve the efficiency of manufacturing process by solving complex industrial tasks reliably and consistently (Arntz et al. 2016). Types of vision systems include 1D vision system, 2D vision system, Line scan or Area scans, and 3D vision system depending on the needs of the industrial process (Gregory 2016). Consequently, new specialty robots are design and customize as machine vision system to meet the owner demand to fulfill the efficient automation process (Cowen 2016).

In this paper, a machine vision system was built comprise of three robotic arm, vision system to detect the defect via imaging, and rotary automated system to solve the defect occurred during manual assembly process at labeling department. An investigation was done to collect production data on assembled module and analyze the defect rate of product.

1.1 Problem Statement

The combination of quality defects such as bail scratches, wrong orientation, bail mismatch, loose bail, dented shell surface and color match of SFP units during assembly process has caused product defect of more than 10%; hence, this has reduced the productivity of finished assembling product and added to manufacturing cost. Current manpower of three persons to assemble the SFP units can be eliminated by introducing the robotic machine to do the assembling task of the product.

2 Methodology

The process flow shows how the project is done step by step to achieve the objectives.

Figure 1 shows the research problem which is quality defects in manual assembly process of SFP module which carry out in labeling department was identified. The root cause of the problems was analyzed, then an automated assembly system integrated with vision system was built to solve the problem. There are two robotic arms for pick and place task, a machine vision system to inspect defect and reject the defected units and a main and sub-rotary system to rotate the units during the assembly process. An investigation on daily assembly process took place for manual assembly and automated assembly system. The recorded data collection conducted for one month to obtain the average productivity and quality rate. The purpose of investigation is to evaluate the capability of robotic automated system to carry out the complex tasks given accurately, if the defects become greater than a re-work or re-improvement need to be done. The main role of robotic automated system built is to reduce defect at mechanical gripper, bail robot arm, robotics vison camera, and two pocket latch and bail nest assembly.

2.1 Quality Defect Rate and Productivity

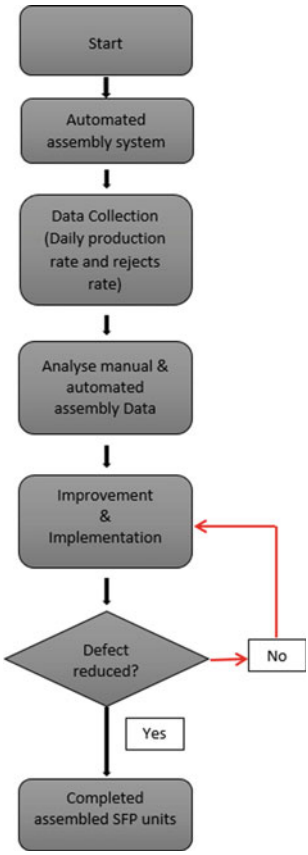
Labeling department was going through some difficulties in achieving the desire production rate in SFP module manual assembly process. The average monthly and daily production rate show that 89.69% while remaining 10.31% contributed to quality defects. Thus, the target is to reduce the quality defect as much as possible to increase the productivity by using the new robotic machine. Hence, the new target was set as below:

- The targeted productivity = 98%
- The targeted quality defects = Less than 2%

2.2 Data Analysis Tool (Bar Charts and Pie Charts)

The bar charts and pie charts were developed to investigate the production rate and quality defects. Comparison on the production rate and defects quality between manual and robotic assembly process is discussed in results section.

Fig. 1 Process flow



3 Results

3.1 Manual Assembly Process

Table 1 shows the monthly data collected for the manual assembly process from December 1 to 31, 2020. The quality defects in manual assembly process identified as given in Table 1. The quality defects are bail scratches, wrong orientation, bail mismatch, loose bail, dented shell surface, and color match. The total failed units represent the sum of all the six quality defects. The total units per day are the production rate while pass units represent the quality inspection pass units. The average units calculated by dividing total days in the month of December 2020.

Figure 2 shows the daily quality inspection passed units versus failed units. The daily and monthly quality defects are 4042 pieces and 125,303 pieces respectively that contribute 10.31% in total production rate. This led to the monthly production rate achieved only 89.69% as shown in Fig. 3. Figure 4 shows the quality defects

Table 1 Manual assembly production rate and defects rate of SFP module in labeling line

	Total Units per day/month	Passed Units	Bail scratches	Wrong orientation	Bail mismatch	Loose bail	Dented shell surface	Color match	Total Failed Units
Sum (monthly)	1,215,169	1,089,866	91,685	5481	18,176	3108	3242	3611	125,303
Count (day)	31	31	31	31	31	31	31	31	31
Average (daily)	39,199	35,157	2958	177	586	100	105	116	4042
Percentage	100%	89.69%	7.55%	0.45%	1.49%	0.26%	0.27%	0.30%	10.31%

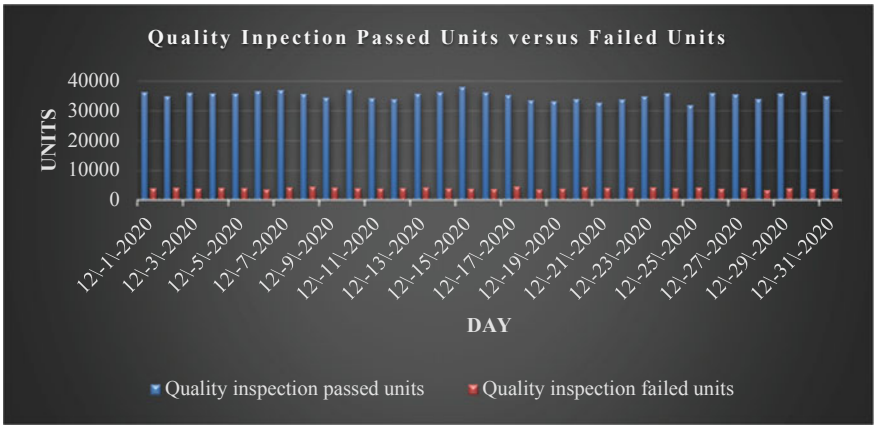


Fig. 2 SFP module daily quality inspection passed units versus failed units

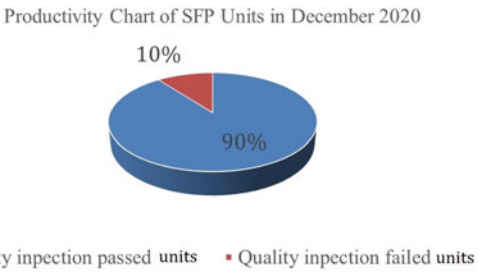


Fig. 3 Productivity chart of SFP units in December 2020

rate as compared to total defect quality rate which showed dented shell surface contributed the highest defects that is 73%. The quality defects are bail scratches, wrong orientation, bail mismatch, loose bail, dented shell surface, and color match. The total failed units of 4042 pieces represent the sum of all the six quality defects. The total units per day are the average production rate while pass units represent the quality inspection pass units.

3.2 Automated Assembly Process

Table 2 shows the data collected in the automated assembly process using the robotic machine from March 1 to 31, 2021. Figure 5 shows the daily quality inspection passed units versus failed units. From the figure we can see that daily the quality defects are reduced to 0.27% from 10.31% in total production rate by using robotic machine. This led to the monthly production rate achieved more than 99.73% as shown in Fig. 6. Apart from that, Fig. 7 shows the various types of quality defects in auto assembly process of SFP units, where the major quality issues are due to bail scratches which

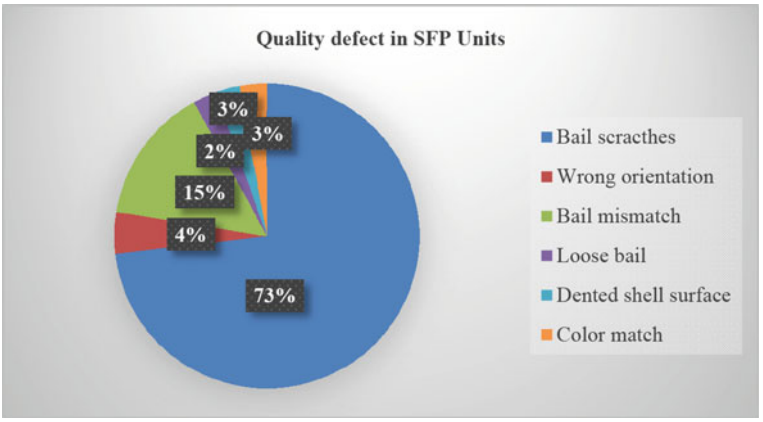


Fig. 4 Quality defects rate which obtained from inspection process

contributed 64% of defects; dented shell surface and loose bail have contributed 22 and 14% to the quality issues. Apart from that, wrong orientation, color match, and bail mismatch have no issues in automation assembly process.

4 Discussion

Table 3 shows the data comparison of both manual and automated assembly processes. The inspection pass unit percentages were 89.69% in manual assembly process, but after the automated assembly process implemented, the production rate has been raised to 99.73%. This showed that the quality defects rate had been reduced from 10.31 to 0.27%. Apart from that, we manage to reduce some of the defects to zero percentage. Wrong orientation, bail mismatch, and color match have no issues in auto assembly process. Furthermore, bail scratches have been reduced from 7.55 to 0.17%. Bail scratches were the major issue which contribute highest percentage among other quality defects. Apart from that, the other two defects were loose bail and dented shell surface which have only very low percentage which is below 0.1%.

Table 2 Manual assembly production rate and defects rate of SFP units in labeling line

	Total units per day	Passed units	Bail scratches	Wrong orientation	Bail mismatch	Loose bail	Dented shell surface	Color match	Total failed units
Sum	1,221,870	1,218,580	2112	0	0	450	728	0	3290
Count (d)	31	31	31	31	31	31	31	31	31
Average	39,415	39,309	68	0	0	15	23	0	106
Percentage	100%	99.73%	0.17%	0%	0%	0.04%	0.06%	0%	0.27%

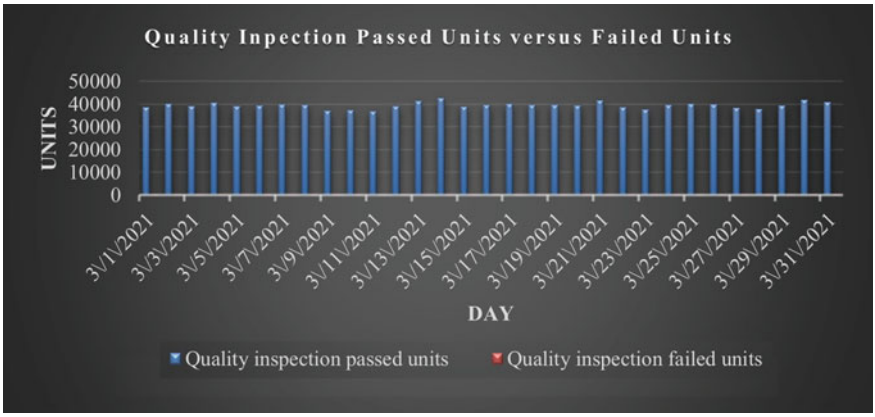


Fig. 5 SFP module daily quality inspection passed units versus failed units

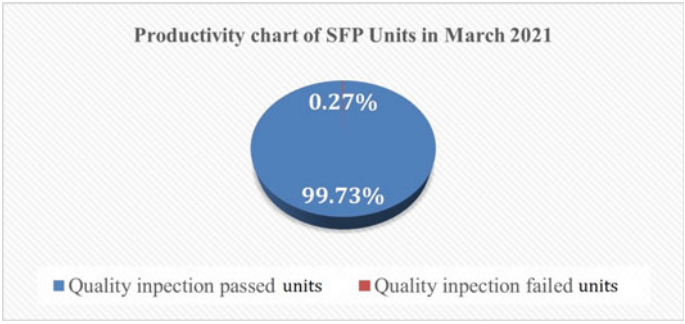


Fig. 6 Productivity chart of SFP units in March 2021

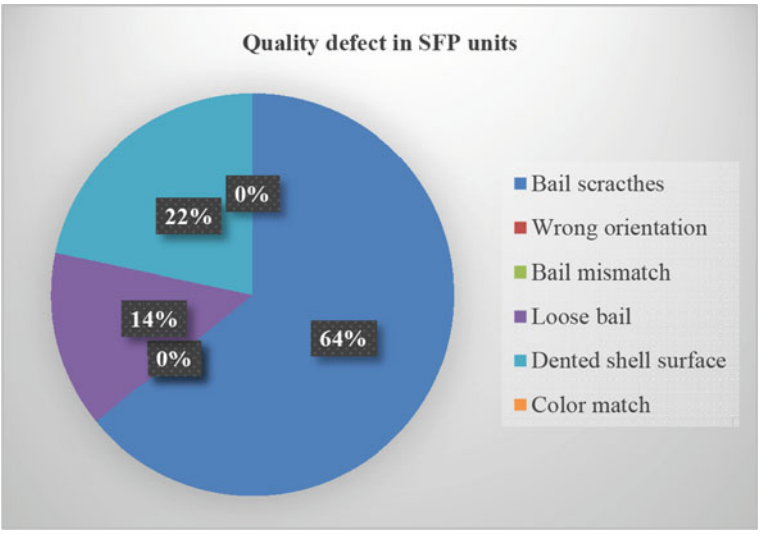


Fig. 7 Quality defects in SFP units after quality inspection

Table 3 Comparison between manual assembly process and automated assembly process

Total units per day	Passed units	Bail scratches	Wrong orientation	Bail mismatch	Loose bail	Dented shell surface	Color match	Total failed units
Manual assembly process								
100%	89.69%	7.55%	0.45%	1.49%	0.26%	0.27%	0.30%	10.31%
Automated assembly process								
100%	99.73%	0.17%	0%	0%	0.04%	0.06	0%	0.27%

5 Conclusion

By implementing the automation assembly process by using robotic machine, all the six (6) quality defects in the manual assembly process have been reduced significantly below 2% with great achievement of only 0.27% total defect quality. This proved that manpower in manual assembly process led to quality defects. As this is a repeated process, humans tend to produce errors while doing the given tasks for long hours. Hence, we can conclude that robotics is specialized in handling sensitive product and component with precise as compared to human manpower. As the results, quality inspection of passed SFP units improved by 10% from 89.69 to 99.73%. This led to achieving 99% of production rate in assembly of SFP units that saw a reduction of 97.4% in total defect quality from 10.31 to 0.27%. Secondly, the major defect of bail scratches is reduced about 97.7% which is a reduction from 7.55 to 0.17%.

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