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SINGLE-DIGIT TIME: TOWARD A QUICK CHANGE-OVER PROCESS WITH THE SMED METHOD USING THE VISION SYSTEM

Hendi Herlambang *, Zulfa Fitri Ikatrinasari, Kosasih Kosasih

Industrial Engineering Department, University Mercu Buana, Jakarta, Indonesia

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Research paper

Abstract: *Increasing the speed of the product change-over process is critical by implementing the Single Minute Exchange of Dies (SMED) effectively. The smallest activity variation between operators, activity speed, and process accuracy are identified research targets. This research was developed in the electronic component industry, where the Define-Measure-Analyze-Improve-Control (DMAIC) and Hierarchy Task Analysis (HTA) methods can describe the most crucial and key activities. Therefore, it takes accuracy and reliability between operators to carry out this activity. This paper presents the acceleration of the product change-over process by developing an automated non-contact inspection method in the assembly area using a vision system. The results of the study illustrate that the change-over process can be carried out in single-digit minutes (7 minutes), or reduced by 81%, and the speed of change-over activities between operators is the same.*

Key words: *SMED, Vision System, Automation, Inspection, Capability process, Electronics component.*

1. Introduction

Image processing techniques used for robot guidance and automatic inspection are called vision systems widely used in the industrial field (Semeniuta et al., 2018). The assembly inspection process is a crucial procedure to perform measurements and detect errors. The dimensional inspection assembly unit is still done manually using a caliper and micrometer that takes a long time, physical contact, and potential difference in measurement between operators (Frustaci et al., 2020). Connolly stated vision system is mighty, compact, and easy to operate even though it is not a programmer, and this is very interesting for the industry (Connolly, 2003). Machine vision has been successfully applied to electronic component companies so that the

* Corresponding author.
hendi_herlambang@yahoo.com (H. Herlambang), zulfa.fitri@mercubuana.ac.id (Z. F. Ikatrinasari), k.kosasih@mercubuana.ac.id (K. Kosasih)

level of automation can be increased (Hendi Herlambang et al., 2021). Therefore, the vision system is an image processing technique that is easy to use in industry, fast, without physical contact, can avoid measurement errors, and can increase the level of automation.

Every organization looking to speed up the transition from one product to another focuses on low cost, speed of delivery, and superior quality. Single Minute Exchange of Dies (SMED) is a lean manufacturing tool that can shorten change-over activities by converting internal time to external time, then streamlining both (Shingo, 1985). Research conducted by Michels concluded that SMED can speed up the change-over process so that direct labor is reduced as a finding (Michels, 2007). Research conducted by Demeter found that inventory can be reduced by applying the SMED method effectively (Demeter & Matyusz, 2011). Several studies have revealed that the combination of equipment repair and development with the 5S program is the goal so that SMED can be implemented effectively (Cakmakci, 2009). There have been several investigations found that the application of SMED can reduce change-over activity by 41% in the press line (Hendi Herlambang, 2020b), 30% in the pharmaceutical industry (Karam et al., 2018), 42.3% in the injection molding industry (Bhade & Hegde, 2020), and 43% in the cork industry (Sousa et al., 2018). To reduce change-over activity significantly, several tools were used to conduct testing by researchers, Rapid Entire Body Assessment (REBA) analysis (Brito et al., 2017), time study method (Simões, 2010), visual stream mapping (Azizi, 2015), and the geometrically based methodology (Nakeenopakun & Aue-u-lan, 2019). Therefore, the acceleration of the transition process from one product to another can be done by choosing the right equipment and technology according to the company's needs.

Based on the description above, there has been little discussion about accelerating the change-over process with the objective of single-digit minutes in the electronic component industry. Therefore, researchers are interested in implementing a system vision to accelerate change-over activities in electronic component companies using the SMED method. At the internal process, the streamline stage is inserted technology elements to achieve the speed of change-over activity in single-digit units of minutes. This study’s results can provide an overview of the change-over process that can be automated using vision systems quickly.

2. Materials and Methods

The study stages of completion use the Define-Measure-Analyze-Improve-Control method used by researchers to produce reliable SMED application research (Shingo, 1985)(Roth & Franchetti, 2010) (H Herlambang, 2020b).

2.1. Define

This research was conducted in electronic component companies in Indonesia, with connector output. Electrical connectors are electrical appliances that connect between electrical circuits, most connectors can be removed or reattached, but some can be permanent.

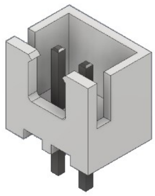


Figure 1. Connector part

Connectors make electronic products easier to assemble and manufacture and make it easier to repair electrical circuits and allow flexibility in design and modification. Connectors are widely used in electrical circuits for communications, computers, industrial machinery, and electronic equipment used by everyone, as seen in Figure 1.

Most connectors consist of two main parts, namely housing and terminals. Housing is a cage or structure used to hold the terminals, stabilize the connection, and protect the contact from short circuits and various hazards caused by the environment. Housing usually consists of several types of printed plastic but can be made of all kinds of insulator materials, as seen in Figure 2, the flow process of connector made.

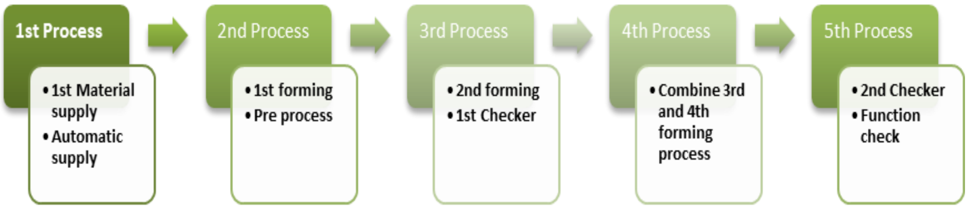


Figure 2. The process flow of making electronic connectors

Production data for one year has been collected to find out productivity indicators. It was found that the 5th process in the change-over activity is the most crucial activity carried out during the change of product type one to another, as seen in figure 2. This activity is carried out repeatedly by the operator manual, and there is physical contact on the product with an average time of 30 minutes. This is in line with Herlambang et al., which states that the product detection system through physical contact can have a large measurement deviation between operators and takes a long time (Hendi Herlambang et al., 2021).

2.2. Measure

At this stage, secondary data collection from each operator is carried out during the change-over process. Data is processed by using Minitab software to find out the ability of the process. The data found that the process capability is still not satisfied with a Cp value of 0.84 and a Cpk value of 0.76, as seen in Figure 3. It is also strengthened that in the Capability Histogram chart, two hills indicate there are two different populations between operators that perform the change-over process.

Initial data analysis is also carried out to determine the direction of Continous Improvement in the future as input to top management. Four blocks of technology and control diagrams are used to visualize current conditions by calculating the value of Z Shift and Z lt at this time. It was found that the current state of technology factors still need to be improved for the capability of the process to increase, as seen in Figure 4.

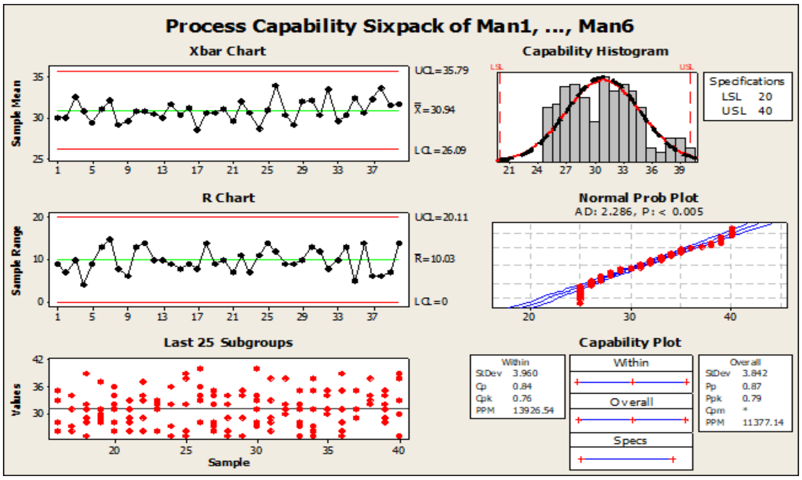


Figure 3. Capability process change-Over activity

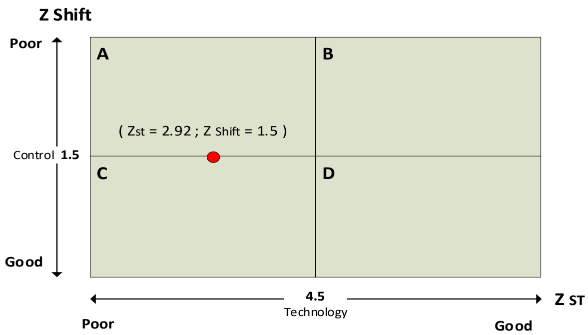


Figure 4. Four Blok diagram Assembly process Activity

2.3. Analyze

At the analysis stage, the authors conducted a more in-depth examination by taking videos to determine the real activities carried out for each operator. To obtain consistency of the observed subjects' natural movements can be recorded using video (Asan & Montague, 2014). This can help the author analyze the operator's movement and then decomposition each activity in detail to see the potential occurrence of errors. Analytical techniques are used to determine human error potential at each work level using Hierarchy Task Analysis (HTA) (Shorrock & Kirwan, 2002). As seen in figure 5, the activity of the change-over process of the replacement checker.

HTA for checker change process has been done decomposition and followed by identifying errors in each activity caused by errors sourced in people and on the information system. As seen in Figure 5, sub-tasks given different colors are the most crucial activities with the most potential for errors.

Task 2.4 and 3.4: Insert parts one by one. Insert small box sticks one by one into the block stick, according to the product to be produced. This process is done manually, and the number of box sticks should not be more or less. The following errors have been identified in this activity :

1. Box sticks amount more or less if done with a decreased concentration level. The operator must calculate the number of box sticks manually and align with the product set up, which will significantly help part installation errors.
2. The box stick is jammed because it is rusty. To prevent this from happening, the operator must perform cleaning and lubrication on the box sticks and stick blocks.

Task 4.1: Manual positioning product with the checker. Alignment process by aligning the product with box sticks, with the aim of optimal checker detection process.

Task 4.2: Check the straightness visually. Inspection using eye visualization is the most important.

If Task 4.1 and 4.2 are not appropriately done, then :

1. Detection of less than maximum wasted products, but products that do not fit the requirements will still be wasted to the scrap box.
2. The machine's ability will go down because often the machine trouble caused by the alignment is not good.

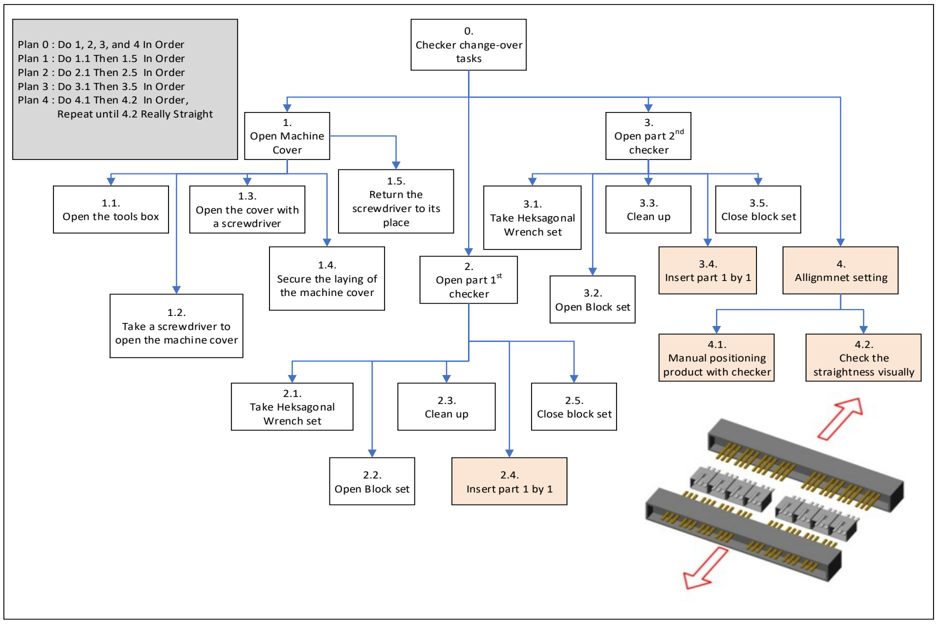


Figure 5. Hierarchy Task Analysis change-over activity

This checker change activity is an activity that authors say requires a high level of concentration and work experience. To prove this hypothesis, the authors conducted tests on two operator populations. The first operator with a working period of more than two years, and the second is with an operational period of fewer than two years, with a hypothesis:

Ho: There is no difference in the speed of change-over activity above 2 years and below 2 years.

H1: There is a difference in the speed of change-over activity above 2 years and below 2 years.

It was found that the Ho hypothesis was rejected, and the H1 hypothesis was accepted, with a p-value< 0.05 as seen in Figure 6, For easier visualization of speed differences between operators, display the plot box diagram for total time change over, as seen in Figure 7, and the detail as seen in Figure 8.

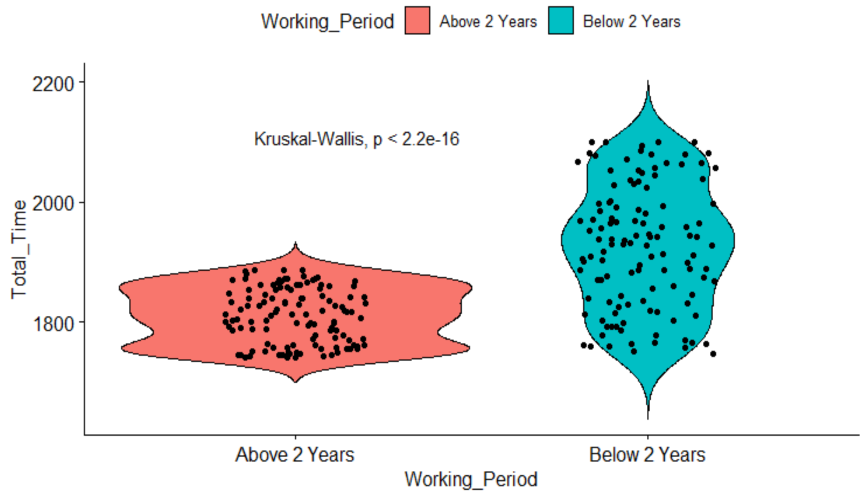


Figure 6. Compare Means Test

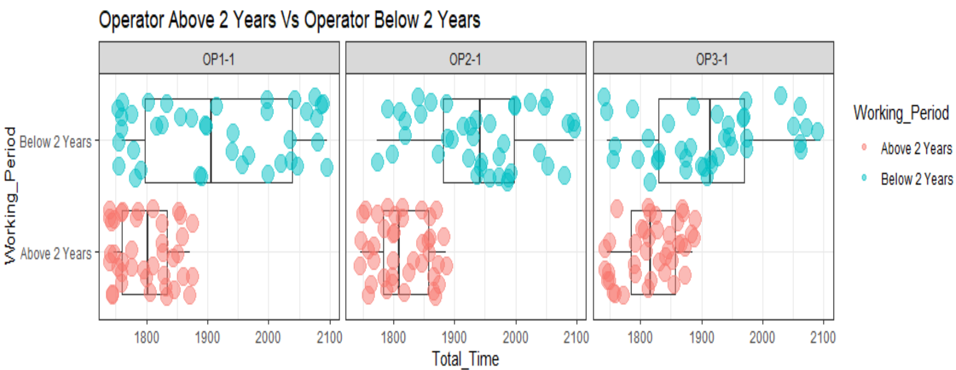


Figure 7. Box Plot Operator Capability

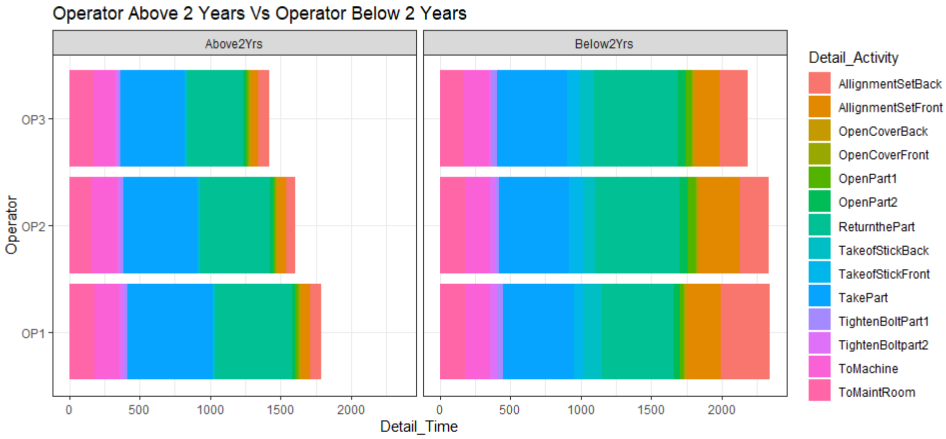
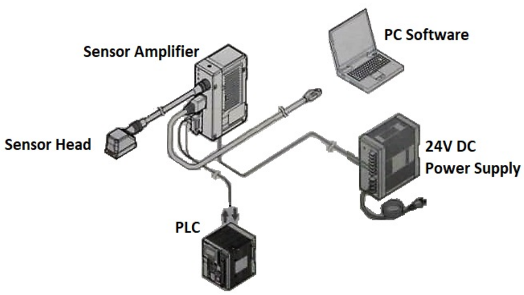


Figure 8. Detail time checker change-over activity

After a more in-depth data check of each operator's activities, it was found that there were significant differences with some operators. As seen in figure 6, the average operator speed of group 1 (Above 2 Years) when doing the change-over activity is 29.7 minutes, and the 2nd group is 37 minutes. Then the standard deviation value of the 1st Operator group is better than the 2nd operator group. So from the analysis of this data, the speed of the 1st group operator and the 2nd group operator is better than group 1 is caused by more extended group 1 operator experience. Although there are already guidelines for the change-over process, skills must be continuously trained so that the operator's ability continues to improve.

2.4. Improve

Internal activities by streamlining change-over activities choose the vision system's application to eliminate the risk of errors, maintain quality factors, and speed up the change-over process. The vision system consists of an object detection module with the sensor head (camera), sensor amplifier, programmable logic controller (PLC), and power supply. As seen in Figure 9 is the configuration system applied to this research.



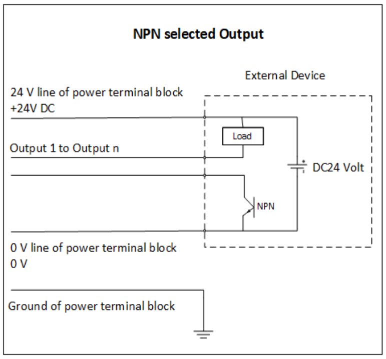


Figure 9. Configuration system Vision System (Keyence, 2019)

Lighting techniques and lights are already integrated with the camera making it easier for researchers to conduct experiments quickly. The camera is mounted at a distance of 220 mm from the object to be detected. The detected object's size is 25 mm, and the system will be mounted on the machine at a speed set by the pneumatic system. The camera acquisition configuration system uses a camera integrated with a led light with a size of 0.5 Megapixels. Objects detected by the vision system are the structure's quality (incomplete part) and the quality of dimensions (following the requirements standards). Experiments for image capture are carried out several times to measure the process's stability, as seen in Figure 11. The detection step with the vision sensor includes;

Step 1. The setting of image optimization

Set the image optimization for clearly imaging the target. Adjust the image for defining the differences in the high and low-quality- target. Set the trigger option, adjust the brightness, and imaging focus, as seen in Figure 10, an external trigger time chart is selected.

(1) Start imaging by inputting the trigger at an arbitrary timing. When the trigger delay interval is set, the imaging start time will be delayed in the specified period.
(2) Performs internal processing after imaging.
(3) Outputs the status result.

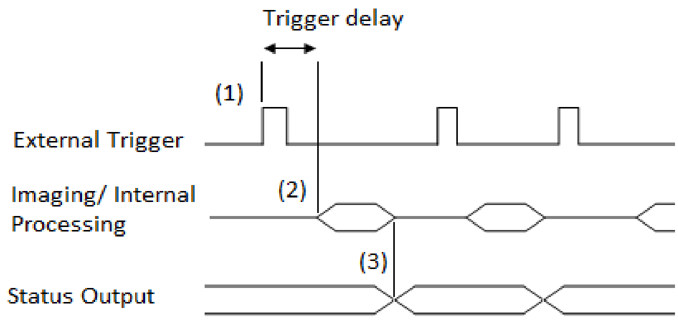


Figure 10. External trigger selected time chart

Step 2. Registration of master image, image the high-quality target, and register the master image to serve as the reference of judgment.

Step3. Tool settings, set the tool to judge a target, set the tool onto the master image, and set the threshold for judgment.

Step 4. Output assignment, assign the function to output to each output line.

The quality of image processing will be better if the field of view (FoV) size is 18 mm x 25 mm with vision sensor distance to objects as far as 50 mm, and field of view (FoV) size of 157 mm x 210 mm with vision sensor distance with objects as far as 500 mm. Not only does the quality of the structure have to be detected by the system, but the quality of the dimensions is also absolutely detected, with the allowed tolerance being below 0.1 mm.

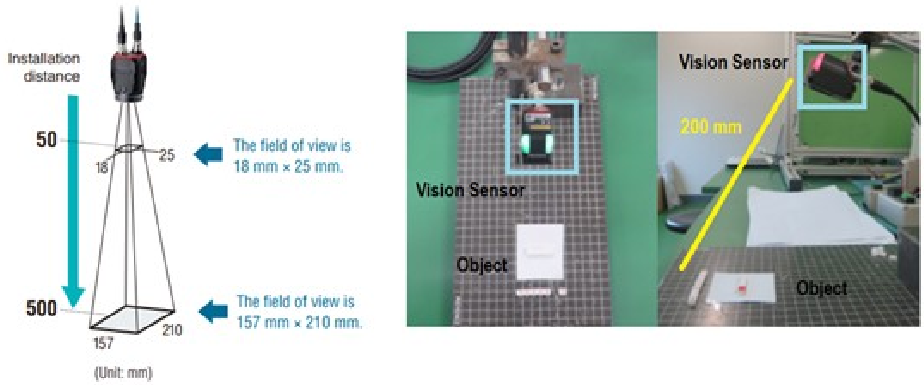


Figure 11. Experiment illustration

2.5. Control

External activities (activities performed while the machine is still running) and convert internal to external processes have been implemented by the company. Eliminating unwritten activities in the order in which the change-over process is intended to make the process run effectively and efficiently (Oakland, 2008)(Hendi Herlambang, 2020a). All change-over activities are documented on the computer by creating graphic visualizations for easy translation by operators.

3. Result and discussion

The experiment has been completed with each product damage results can be well detected by vision sensors. Then the author checks the accuracy of output data from the Vision sensor by using the statistic test with gage study, as seen in Figure 12.

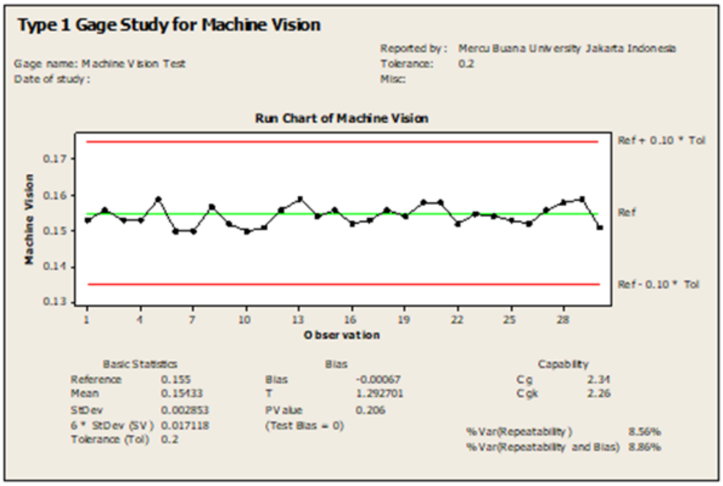


Figure 12. Gage Study Vision system

As seen in figure 12, data stability testing on dimensional measurement is excellent, with a Cg value of 2.34 and a Cgk value of 2.26. Furthermore, this is strengthened by repeatability and repeatability-bias values with 8.56% and 8.86% values, respectively. The structure's quality is collected from the findings of the findings that have occurred and done grouping each product defect's quality. As seen in Figure 13, the output of the vision system can capture well the standard product (A), defects in the product structure in the housing (B), and defects in the product structure on the pin (C).

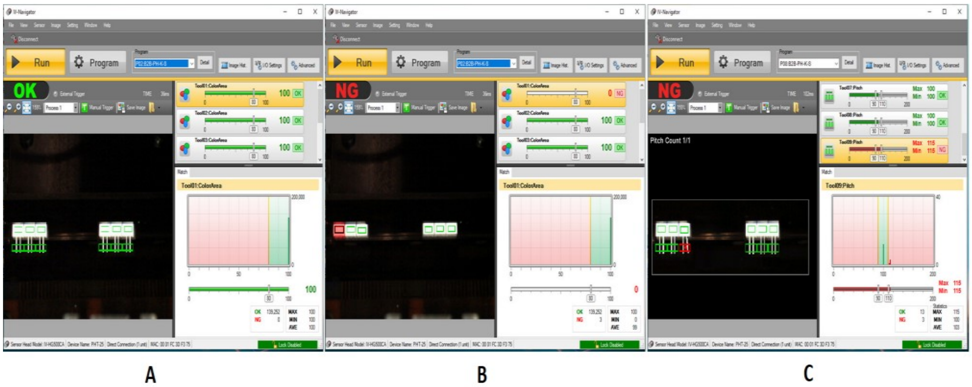


Figure 13. Output vision sensor

The total time required to change one type of product to another is 6 minutes. So that change-over checker activity can be reduced significantly with detection level also increased to non-contact detection. Thus, the HTA table activities, as seen in figure 5, ranging from the 1st activity to the 4th activity, can be eliminated, with minimal risk of failure. After the experiment is complete, the authors validate each operator's measurement results using a new method of system vision. This is done to find out the shift in Z value from technology and control factors. From the results of data processing, it is seen that there is an increase in the level of quality in the quadrant of technological factors as seen in figure 14.

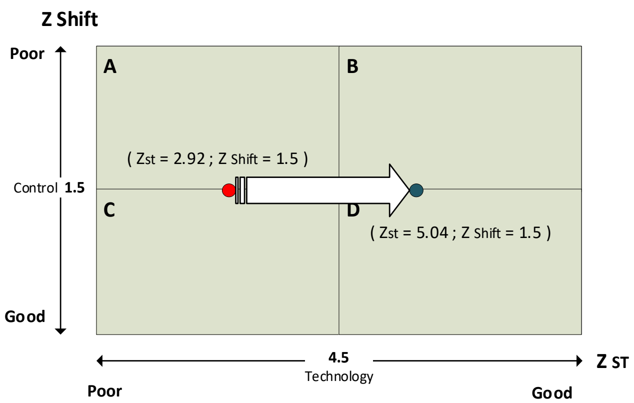


Figure 14. Four blocks quadrant after evaluation using the Vision system

3. Conclusion

The purpose of this study was to determine the effect of adding elements of technology (vision system) to the speed of the change-over process carried out by operators with different working periods. The findings of this study make several contributions to the current literature. First, the use of a vision system in electronic companies can speed up the change-over process within 7 minutes, previously it was 37 minutes, as seen in figure 15. This achievement succeeded in achieving the single-digit minute target. Second, the use of the vision system can be done easily for operators with different working periods. Third, the variation in the speed of both change-over activities is small, so it can be said that the speed of the change-over process is the same for both. The change over process activity has been explained using the Hierarchy Task Analysis (HTA) method. Fourth, four main manual activities can be eliminated after implementation with the vision system, so that measurement errors and measurement bias can be avoided. This research is limited by the size of the target object. One source of weakness in this study that can affect the length of change-over activity is the size of the product detected. Thus, further research is required for a vision system that can be used for common product sizes but has an optimal Field of View (FoV) value.

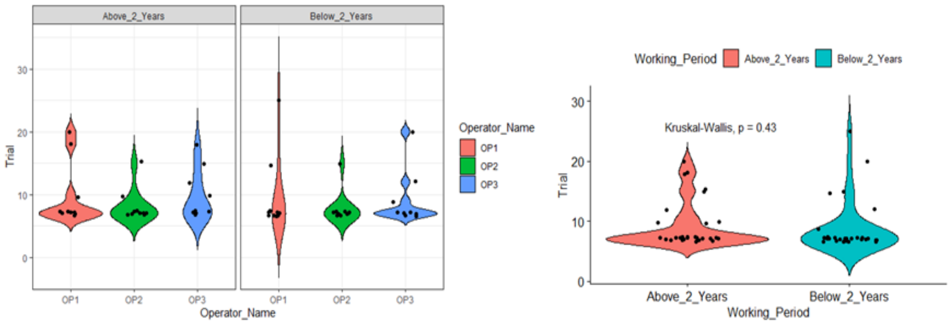


Figure 15. Result chart after improvement implementation

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